**APPROVED**
**Chairman of the**
**Aircraft Accident Investigation Commission**
**Deputy Chairman of the**
**Interstate Aviation Committee**

A. N. Morozov

«12» April 2022

# INTERSTATE AVIATION COMMITTEE
# AIRCRAFT ACCIDENT INVESTIGATION COMMISSION

## FINAL REPORT
## ON THE RESULTS OF THE AVIATION INCIDENT INVESTIGATION

Event type: Accident

Aircraft type: A321-211

State registration number: VQ-BOZ (Bermuda)

Lessor: ACG Aircraft Leasing Ireland Limited

Operator: Ural Airlines

Local aviation authority: Rosaviatsiia Central Interregional Territorial Air Transport Authority

Event location: Moscow Oblast, Russia, 7,990 meters from Ramenskoe Airport on a true bearing of 115˚, coordinates 55˚30’039.00” N, 38˚15’09.24” E

Date and time: 15/08/2019, 06:15 local time (03:15 UTC), in daylight conditions

In accordance with the Standards and Recommended Practices of the International Civil Aviation Organization, this report has been released for the sole purpose of preventing aviation accidents.

The investigation detailed in this report does not suggest the apportionment of any kind of guilt or responsibility.

Criminal aspects of this incident are handled by a separate criminal trial.

THIS IS AN UNOFFICIAL ENGLISH TRANSLATION. The original report in Russian is the work of reference.

*Translated by Kyra Dempsey, a.k.a. Admiral Cloudberg, MA Slavic Languages and Literatures, CU Boulder*

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**List of acronyms and abbreviations used in this report**

| | |
|---|---|
| AAIC | Aircraft Accidents Investigation Commission |
| AC | Alternating Current |
| AIP | Aeronautical Information Publication |
| AFM | Airplane Flight Manual |
| AP | Autopilot |
| APCH | Approach |
| APU | Auxiliary Power Unit |
| BCAA | Bermuda Civil Aviation Authority |
| BEA | Bureau of Inquiry and Analysis (French: Bureau d'Enquêtes et d'Analyses) |
| CABS-89 | Civil Aviation Bird Safety Manual of 1989 |
| CAMC-2002 | Civil Aviation Medical Certification for controllers, flight attendants, cadets, and pilot candidates, approved by the Russian Ministry of Transport 22/04/2002 |
| CAT | Category |
| CFDIU | Centralized Fault Display Interface Unit |
| CRM | Crew Resource Management |
| CVR | Cockpit Voice Recorder |
| DFDR | Digital Flight Data Recorder |
| EASA | European Aviation Safety Agency |
| ECAM | Electronic Centralized Aircraft Monitor |
| EGT | Exhaust Gas Temperature |
| EIU | Engine Interface Unit |
| ELAC | Elevator Aileron Computer |
| EVM | Engine Vibration Monitor |
| FAC | Flight Augmentation Computer |
| FADEC | Full Authority Digital Engine Control |
| FAR | Federal Aviation Regulations [Russian Federation, not to be confused with US FARs] |
| FARFA | Federal Aviation Regulations for Flights in the Airspace of the Russian Federation |
| FCDC | Flight Control Data Concentrator |
| FCTM | Flight Crew Techniques Manual |
| FD | Flight Director |
| FDR | Flight Data Recorder |
| FMGC | Flight Management and Guidance Computer |
| FOM | Flight Operations Manual |
| FIR | Flight Information Region |
| FL | Flight Level |
| FOM | Flight Operations Manual |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| IFR | Instrument Flight Rules |
| ITA | Interregional Territorial Administration |

| | |
|---|---|
| MAC | Mean Aerodynamic Chord |
| MAK | Interstate Aviation Committee (Rus. Межгосударственный авиационный комитет) |
| MCDU | Multi-function Control and Display Unit |
| MEL | Minimum Equipment List |
| MGU | Moscow State University (Московский государственный университет) |
| NVM | Non-Volatile Memory |
| $N_1$ | Fan rotation speed |
| OGV | Outlet Guide Vanes |
| PB | Pushbutton |
| PBN | Performance-Based Navigation |
| PFD | Primary Flight Display |
| PFR | Post Flight Report |
| PIC | Pilot In Command |
| QFE | Altimeter setting relative to airfield elevation |
| QNH | Altimeter setting relative to sea level |
| QRH | Quick Reference Handbook |
| RAT | Ram Air Turbine |
| RNP | Required Navigation Performance |
| RNAV | Area navigation |
| RVR | Runway Visibility Range |
| RVSM | Reduced Vertical Separation Minima |
| SEC | Spoiler-Elevator Computer |
| SMPA | Standardized Multi-factor Personality Analysis |
| SRS | Speed Reference System |
| TAF | Terminal Airport Forecast |
| TCAS | Traffic Collision Avoidance System |
| $V_1$ | Decision speed |
| $V_2$ | Takeoff safety speed |

**Executive Summary**

On 15/08/2019, at 06:15 local time (03:15 UTC),[1] the Ural Airlines A321-211 aircraft (henceforth, A321) VQ-BOZ was involved in an accident after takeoff from Runway 12 at Ramenskoe Airport. The aircraft was operating scheduled passenger flight SVR178 from Zhukovskiy Airport (UUBW) to Simferopol Airport (URFF). There were two flight crew members, five cabin crew members, and 226 passengers (221 Russian citizens, two citizens of Belarus, two citizens of Kazakhstan, and one citizen of Ukraine) on board the aircraft.

Immediately after liftoff from the runway, a bird strike took place. The remainder of the flight lasted about one and a half minutes, after which the aircraft landed in a cornfield. The aircraft was substantially damaged, and 27 passengers and one crewmember received injuries of varying severity.

Notice of the accident reached the MAK at 06:57 on 15/08/2019.

The investigation of the accident was conducted by a commission appointed on 15/08/2019 by order No. 20/922-r of the Chairman of the Aviation Accidents Investigation Commission (AAIC) of the MAK.

| | |
|---|---|
| Chairman of the Commission | **Kulinskiy, K. A.**, Consultant, AAIC MAK |
| Deputy Chairman of the Commission | **Goriunov, B. A.**, Deputy Chairman of the MAK Flight Safety Monitoring, Analysis, and Expertise Commission |
| Members of the Commission | **Averkiev, A. A.**, Deputy Head of Rosaviatsiia Airport Authority |
| | **Komakhin, S. V.**, Specialist, Central Rosaviatsiia ITA, Domodedovo Airport Flight Safety Management Department |
| | **Konovalov, I. M.**, Consultant, MAK Commission for Data Analysis and Processing, Complex Scenario Modeling, and Software Technology |
| | **Pershikov, N. A.**, Advisor, MAK Flight Safety Monitoring, Analysis, and Expertise Commission |

Chebrov, R.I., Head of Flight Safety Inspections at Ural Airlines, was added to the Commission on 19.08/2019 by order No. 20A/922-r of the Chairman of the AAIC MAK.

On 19/05/2020, by order No. 7.1892/TsMTU of the Deputy Head of the Central Rosaviatsiia ITA, concerning the firing of **Komakhin, S. V.,** Specialist, Central Rosaviatsiia ITA, Domodedovo Airport Flight Safety Management Department, **Bez'iazykov, S. K.**, Specialist, Central Rosaviatsiia ITA Flight Safety and Aviation Incident Investigation and

[1] Henceforth, UTC time is used unless otherwise indicated; local time is UTC + 3.

Mitigation Department, was added to the Commission (order No. 20B/922-r of the Chairman of the of the AAIC MAK, 20/05/2020).

In connection with the firing of **Pershikov, N. A.**, Advisor, MAK Flight Safety Monitoring, Analysis, and Expertise Commission, **Kiselev V. Iu.**, Head of the Aviation Incidents Investigation Department of the AAIC MAK, was added to the Commission (order No. 20V/922-r of the Chairman of the AAIC MAK, 15/09/2020).

In accordance with Annex 13 of the Chicago Convention on International Civil Aviation, "Investigation of Aviation Accidents and Incidents," notice of the accident was sent to the BEA (France), the aircraft accident investigation authority of the state of aircraft manufacture; and to the AAIB (United Kingdom), the aircraft accident investigation authority for the overseas territory of Bermuda, the state of aircraft registration. These states appointed accredited representatives to participate in the investigation.

Advisors from Airbus, the aircraft manufacturer; CFM International, the engine manufacturer; and EASA were appointed to accompany the BEA representative and participated actively in the investigation.

Representatives of Rosaviatsiia, Ural Airlines, the M. M. Gromov Flight Institute, and other organizations also participated in the investigation.

Initial activities at the accident site (evacuation of passengers and securing of the accident scene) were conducted by personnel from the Russian Federation Ministry of Emergency Situations, the M. M. Gromov Flight Institute, and Zhukovskiy Airport. During the composition of this report, evidence submitted by these organizations was taken into account.

Investigation initiated — 15/08/2019

Investigation concluded — 12/04/2022.

A criminal trial concerning this accident was initiated by the Moscow Air and Water Transportation Investigation Department of the Moscow Interregional Transportation Investigation Administration of the Investigative Committee of the Russian Federation.

## 1. Factual Information

### 1.1 History of the Flight

On 15/08/2019, an Ural Airlines flight crew consisting of a Captain and First Officer were scheduled to fly an A321 with registration VQ-BOZ on regularly scheduled flight SVR178 from Zhukovskiy Airport (UUBW) to Simferopol Airport (URFF). The aircraft's previous flight, which was carried out by a different crew, landed at 01:31. No takeoffs or landings occurred at the airport after this.

Between 01:42 and 01:57, the crew members underwent a pre-flight medical check at the office of the Central Flight Staff Clinic at Zhukovskiy Airport, where they were found medically fit to fly and their status was recorded by medical personnel in the flight crew pre-flight medical inspection log.

The pre-flight preparation of the aircraft (line maintenance in the form of a DAILY check (DY)) was conducted on 14/08/2019 at Zhukovskiy Airport by FL Technic specialists (work order No. OZD283Aug, 14/08/2019).

According to the flight manifest, flight SVR178 carried 226 passengers and 1,752 kilograms of baggage; there was no cargo. After the addition of 15,936 kilograms of fuel, the total aircraft weight was 82,167 kilograms and its center of gravity was 25.7% MAC. These values were within the limitations established by the FOM (a maximum takeoff weight of 89,000 kilograms and a takeoff center of gravity range between 17.2 and 29.9% MAC).

At 03:12, the crew initiated takeoff from Runway 12. While giving the takeoff clearance, the controller warned the crew about the possible presence of birds. Immediately after liftoff from the runway (at a distance of 2 kilometers before the departure end), the aircraft collided with a flock of birds (numerous fragments of which were discovered in various parts of the aircraft and on the ground). The flight recorders captured a change in engine power. The crew continued the flight; however, they were unable to maintain altitude. At 03:15 the aircraft landed in a cornfield. The aircraft came to rest 5,300 meters from the departure end of Runway 12 and 815 meters left of its extended centerline. There was no fire. The crew conducted an emergency evacuation. After the activation of the emergency alarm at Ramenskoe Airport and the arrival of airport rescue services, the passengers were evacuated from the accident site and the injured were transported to medical facilities.

### 1.2. Injuries to Persons

| Injury type | Crew | Passengers | Others |
|---|---|---|---|
| Fatal | 0 | 0 | 0 |
| Serious | 1 | 2 | 0 |
| Minor/None | 0/6 | 25/199 | 0/0 |

### 1.3. Damage to Aircraft

An inspection of the aircraft was conducted on 15/08/2019 during daylight conditions. An exterior view of the aircraft after the accident is shown in Fig. 1.

*Figure 1. The A321 VQ-BOZ after the accident*

The nose cone had several breaks and indented panels (Fig. 2).

*Figure 2. Exterior view of the nose cone*

A left rear fuselage panel had numerous deformations with a corrugated appearance (Fig. 3). The left wing root fairing was damaged and some parts were missing.

*Figure 3. Corrugations on an aft fuselage panel*

Corrugated panels were found on the lower part of the fuselage between frames 09 and 10, and on the right side of the fuselage (Fig. 4).

*Figure 4. Corrugations on a lower right fuselage panel (indicated by the arrow)*

The lower forward part of the fuselage had deformed panels and fairings (Fig. 5).

*Figure 5. Exterior view of the lower forward fuselage*

The lower aft fuselage had numerous deformed panels and fairings (Fig. 6). The water supply system access hatches were missing. The sewage system access hatches were damaged and deformed.

*Figure 6. Exterior view of the aft fuselage*

The right wing root fairing was damaged and partially missing (Fig. 7).

*Figure 7. Exterior view of the lower center fuselage*

Destruction of the wing structure did not occur. The following damage to the wings was observed:

- The lower panels of the wing console had numerous deformations.
- The right wing console end fairing was missing.
- The leading edges of the right and left wings received mechanical damage (Fig. 8 and 9).

*Figure 8. Damage to the right wing: а) overview; б) damage in the area of the wing root; в) damage in the wingtip area*

*Figure 9. Damage to the left wing: а) in the wing root area; б) near the engine; в) in the wingtip area*

Bird plumage was found in the gap between left wing leading edge sections 2 and 3 (Fig. 10).

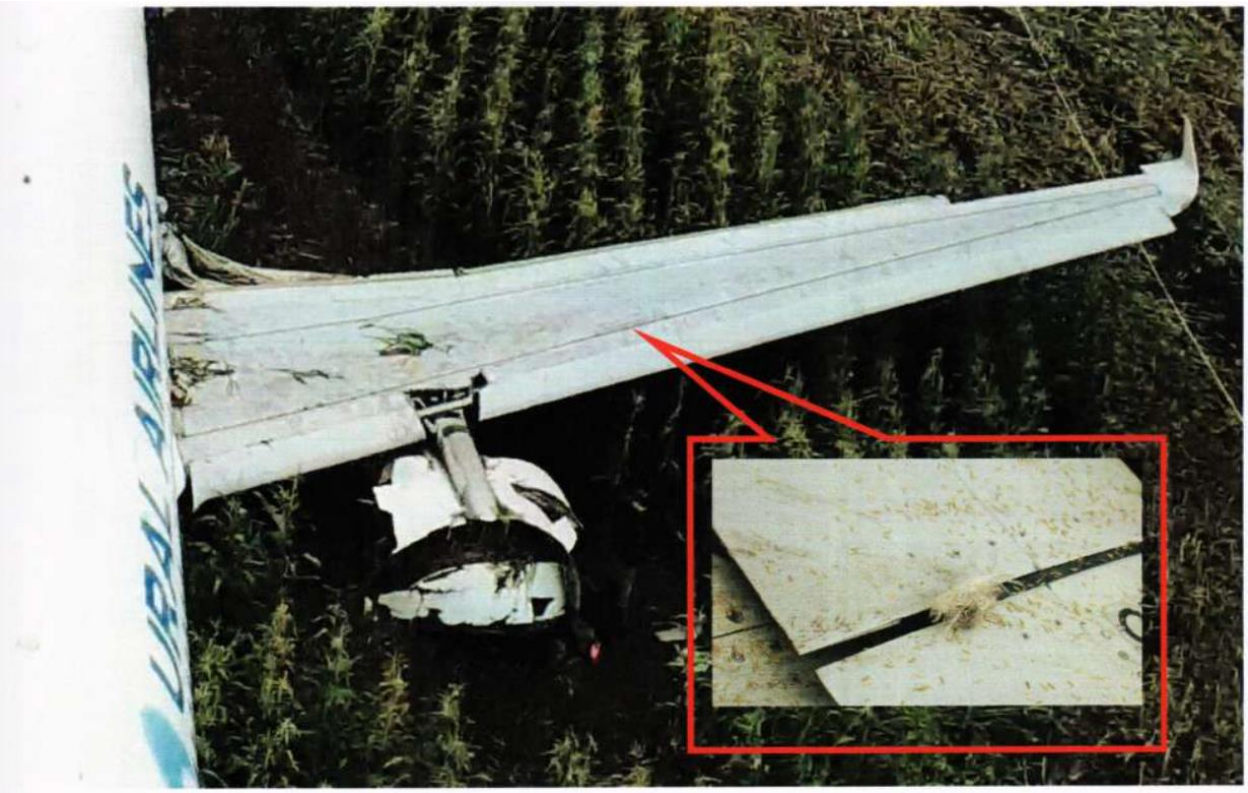



*Figure 10. Bird plumage between the second and third sections of the left wing leading edge*

There was a hole in a panel on the leading edge of the right horizontal stabilizer (Fig. 11).

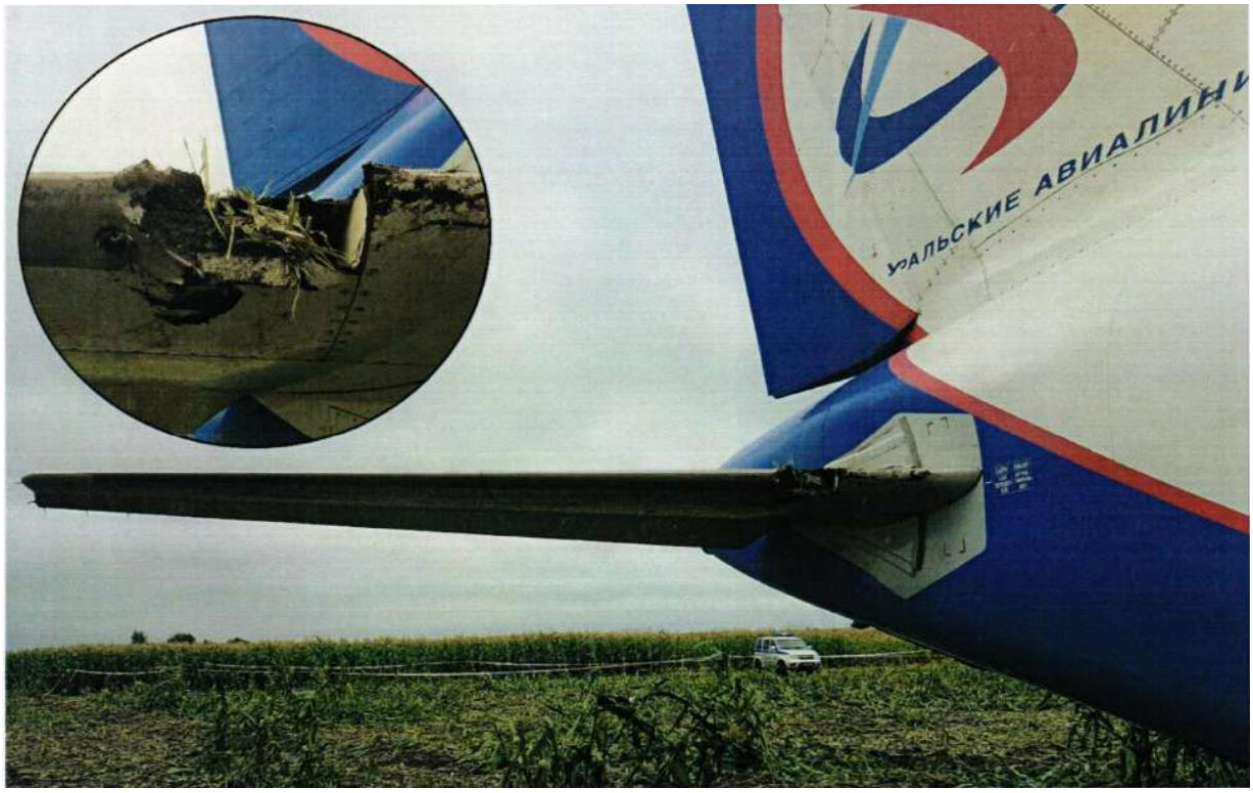


*Figure 11. Damage to the leading edge of the right horizontal stabilizer*

**Doors, Hatches, and Windows**

The eight passenger doors were open and had no visible damage. The eight emergency slides were found in the deployed position.

The forward baggage door was closed. There were deformations to its panels and internal structure (Fig. 12). The aft baggage door was closed and had deformed panels and internal structure. Access to the rear baggage compartment after the accident was accomplished via another door that did not have mechanical damage (Fig. 13). The left and right cockpit windows were open.

*Figure 12. Forward baggage door*

*Figure 13. Aft baggage door*

**Fuel System**

The accident did not result in the fracture of the fuel tanks or damage to the fuel lines, with the exception of a break in the No. 2 engine fuel feed line. No fuel spillage occurred.

**Landing Gear**

The nose landing gear was found in the retracted position without any visible exterior damage; no traces of hydraulic fluid were found. The gear uplock was closed (Fig. 14). The nose gear doors had separated from the aircraft and were found along the surface wreckage trail.

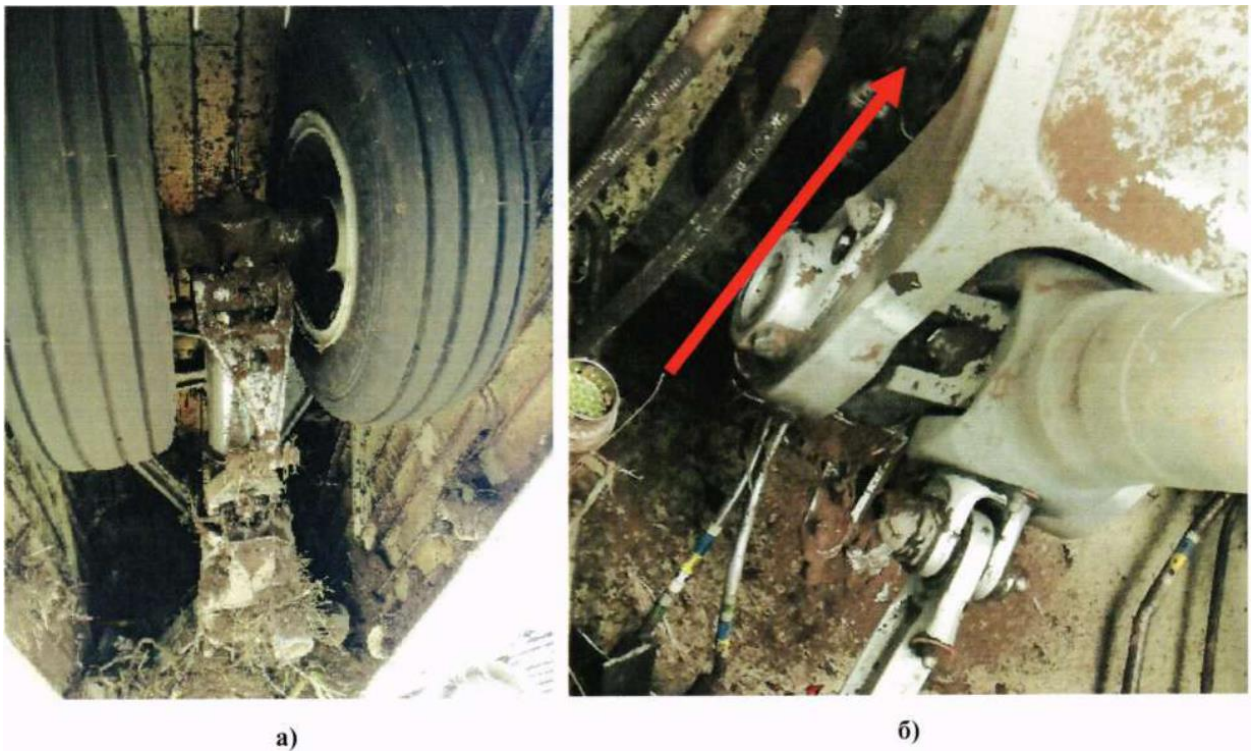



*Figure 14. Nose landing gear (а) and gear uplock (б), indicated by the arrow*

The left and right main landing gear were found in the retracted position. No visible damage to the main landing gear was observed. The gear uplocks were both found in the closed position with the attachment rings in the lock holes corresponding to the retracted position (Fig 15).

*Figure 15. Main gear locks in the retracted position: left (a) and right (б)*

The left main landing gear door lock was found attached to the airframe in the open position (Fig. 16). Because of the position of the aircraft, the right main landing gear and nose gear door locks were not accessible. The doors themselves had separated from the airframe.

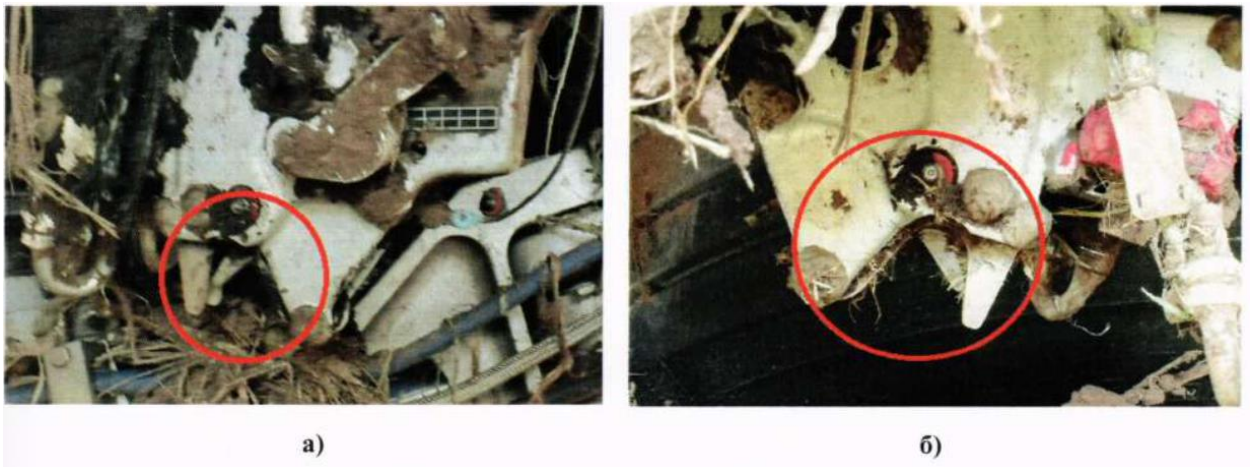



*Figure 16. Left (a) and right (б) landing gear door locks*

The accident did not result in the separation of the main landing gear. Disconnection of wiring harnesses and hydraulic hoses also did not occur.

Bird fragments were found in the left wheel well (Fig. 17 and 18).

*Figure 17. Bird fragments in the left wheel well*

*Figure 18. Bird fragments in the left wheel well*

**Lift Devices**

The leading edge slats and trailing edge flaps were found deployed in the "CONF 1+F" position ($\Delta pr = 18^\circ$, $\Delta z = 10^\circ$).

The right wing leading edge slats had numerous deformations and broken panels. The left wing leading edge slats had numerous deformed panels.

Disconnection of the slat control system components did not occur.

The flaps had numerous deformed panels and structural damage. The exterior fairing of the outboard right flap was destroyed as a result of the accident. Disconnection of the flap control system components did not occur.

**Power Plants**

Upon inspection of the engines it was observed that the cores of both engines contained damage and evidence of interference between adjacent components (Fig. 19). Crushed plant matter was found in the intakes of both engines, which impeded detailed inspection of the damage to the fan stages.

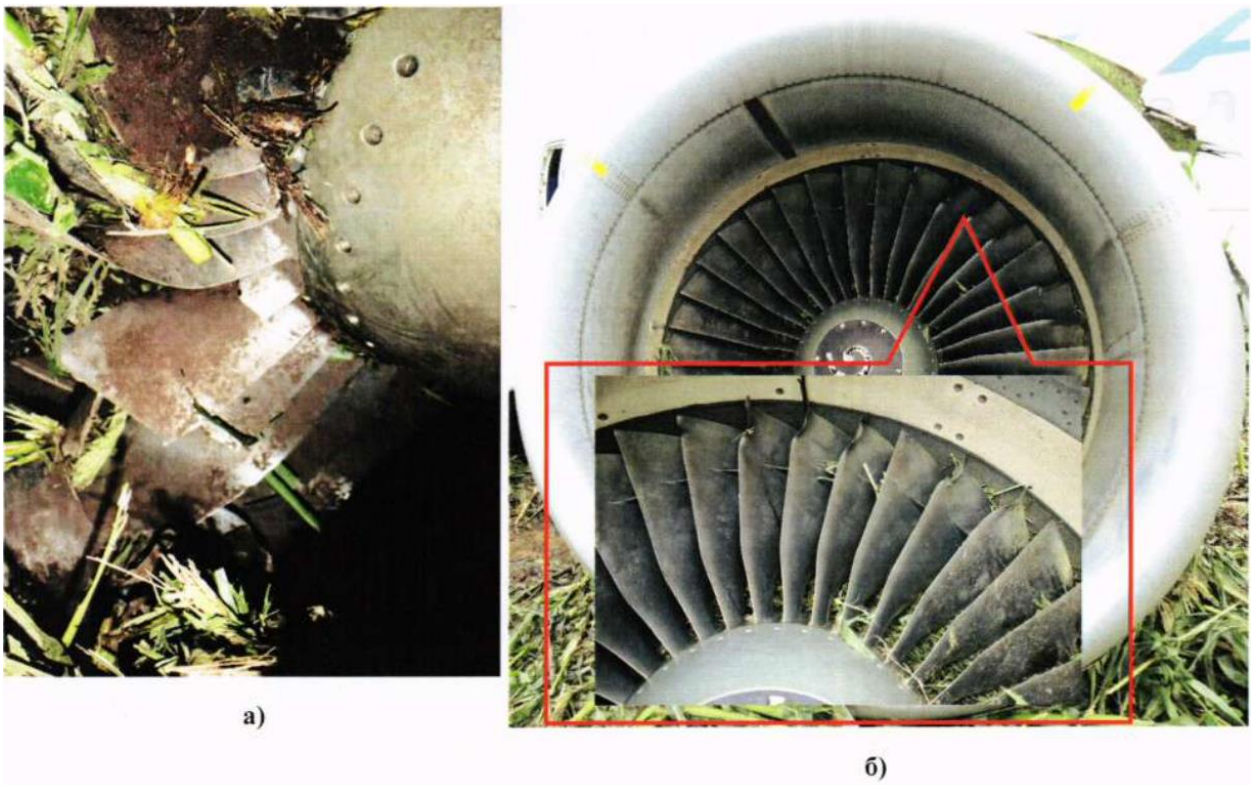



*Figure 19. Exterior view of the No. 1 (а) and No. 2 (б) engine fan stages*

The structure of the No. 1 engine was seriously deformed; the fan blades were deformed and partially torn. The inlet cowl, engine cowling, and reverser cowling were deformed and partially destroyed. Various assemblies in the lower part of the under-cowling area were displaced from their attachment points, and some assemblies were separated from the engine (Fig. 20). The pylon and wing attachment points were deformed.

*Figure 20. Damage to engine No. 1: а) view from the left; б) view from the right*

The structure of the No. 2 engine was seriously deformed (Fig. 21). The fan blades had mechanical damage. The pylon, inlet cowl, forward cowling, and reverser cowling were noticeably damaged. The pylon was destroyed. The engine did not separate from the aircraft.

*Figure 21. Damage to engine No. 2: а) view from the left; б) view from the right*

The No. 1 engine's right reverser doors were found behind the engine, near the tail section. The left reverser doors were found in their nominal position. All four doors were slightly open. The main locks[2] on the right reverser doors were found in the closed position, while the same locks on the left reverser doors were found in the open position. All of the main locks displayed witness marks caused by contact with surrounding metal components.

Measurements showed that the push rods of all four hydraulic reverser door actuators on engine No. 1 were extended symmetrically. Deformation of the doors, damage to the surrounding structure, and the two open locks were most likely the result of ground impact.

Three reverser doors on engine No. 2 were found in a slightly open position, while the position of the fourth door could not be assessed at the accident site because it was not accessible.

The hydraulic actuators for all four reverser doors on the No. 2 engine were found in the stowed position, indicating that the doors were physically stowed at the moment of impact.

It was not possible to assess the position of two of the main locks. The third lock was broken. The fourth lock was found in the open position.

Inspections and measurements indicated that the No. 2 reverser doors were locked at the time of impact. All damage occurred as a result of the accident.

The ram air turbine (RAT) and its mounting were separated from the aircraft and its blades were deformed (Fig 22). Parts of the lower fuselage fairing that covers the turbine were found before the water-filled trench along the aircraft's ground trajectory (see section 1.12 of this report). The turbine itself was found after the trench. The fact that the turbine was found farther along the debris path than the first main landing gear fragments indicates that the turbine separated as a result of ground impact and was not deployed during the flight. This agrees with the DFDR data, according to which there were no AC power interruptions from either bus during the flight, and therefore no reason to deploy the turbine.

[2] A description of the thrust reverser system design is included in section 1.18.9 of this report.

***Note:*** *According to the FCOM (DSC-24-10-30-30 P 8/18), the RAT will deploy automatically if the speed of the aircraft is above 100 knots and there is a loss of AC electrical power from both buses (AC bus 1 and AC bus 2). During the accident flight, there was no loss of electrical power until the end of the recorded data. The cessation of the recording occurred after the aircraft first impacted the ground. According to the crew, the RAT was not deployed manually either.*

*Figure 22: Ram Air Turbine*

**APU**

The APU was found in its normal location. There was no visible damage to the APU or any of its attachment points.

**Avionics Equipment (Control Panels)**

Upon inspection of the cockpit, it was observed that the control panels did not have any visible mechanical damage or any evidence of influence by moisture.

The following positions of accumulator switches (Fig. 23), fire extinguisher handles (Fig. 23), and engine start switches (Fig 24) were observed. The APU FIRE switch (Fig. 23, position No. 3), ENG 1 FIRE switch (Fig 23, position No. 1), and ENG 2 FIRE switch (Fig. 23, position No. 2) were found in the “engaged” positions. The AGENT switches, which inject extinguishing

agent into the engines and APU, were simply buttons which return to their original position after being pressed (Fig. 23, positions 4, 5, 6, 7, and 8). The successful discharge of the containers of extinguishing agent would have been indicated to the crew via the illumination of the corresponding indicator light, the status of which cannot be observed on when the aircraft is unpowered. According to the Captain, the extinguishers were not discharged.

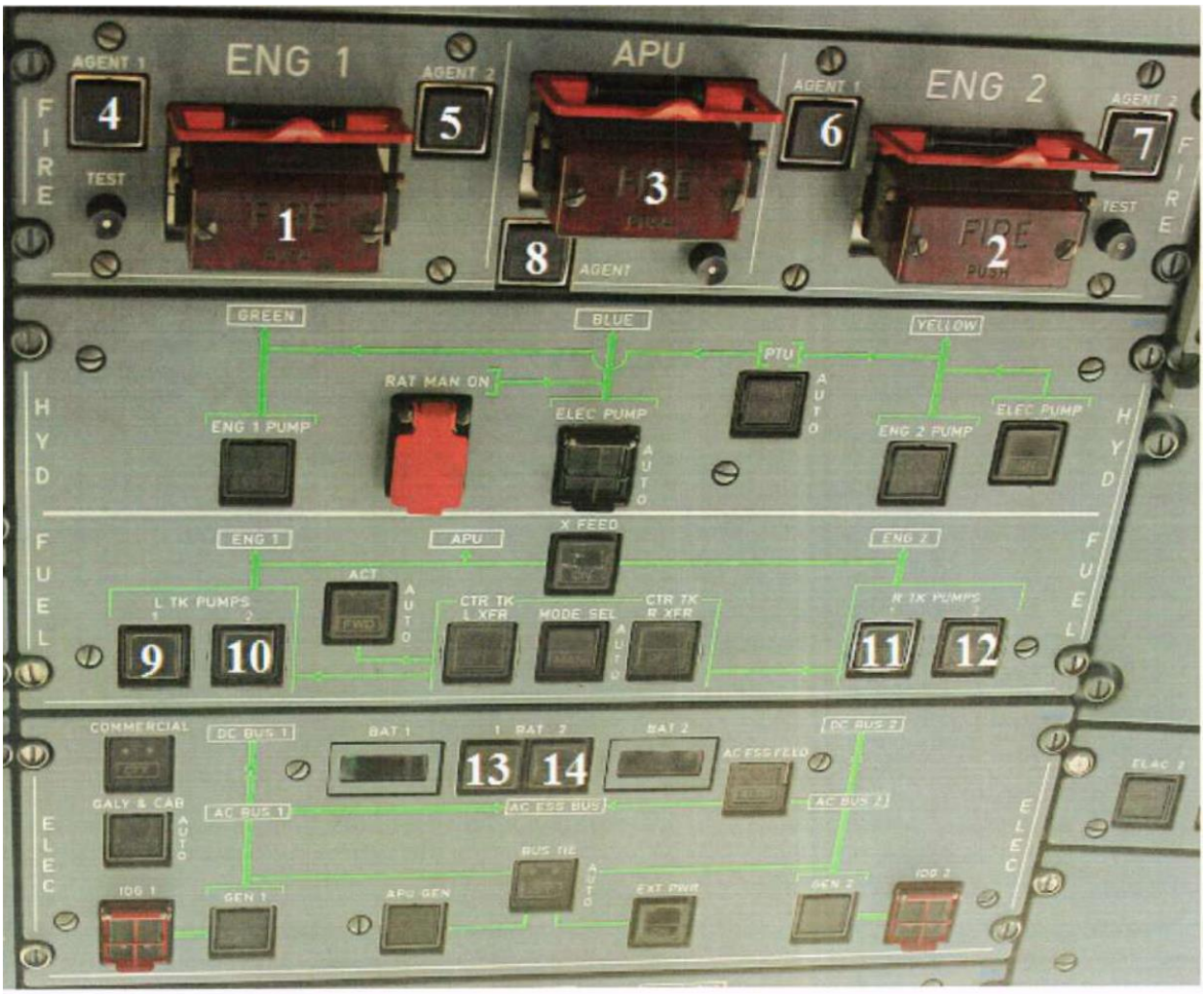



*Figure 23. Upper control panel*

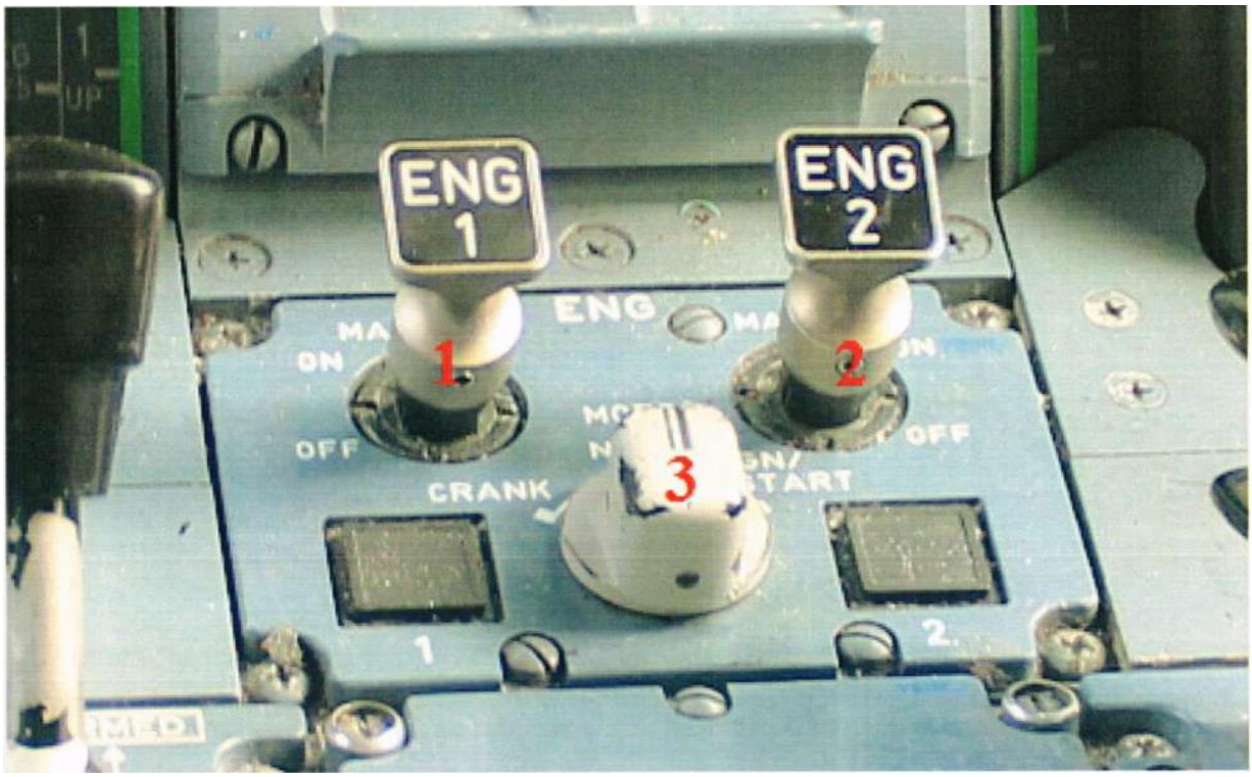



*Figure 24. Position of the engine start switches at the accident site*

The two battery accumulator switches were found in the cutoff position (see Fig. 23, positions 13 and 14).

The main engine start switches (see Fig. 24), ENG MASTER 1 (position No. 1) and ENG MASTER 2 (position No. 2), were found in the OFF position. The mode selector switch (position No. 3) was found in the NORM position.

The flaps and slats were controlled using the FLAPS lever, located on the center console. The lever was found in position 1 (Fig. 25).

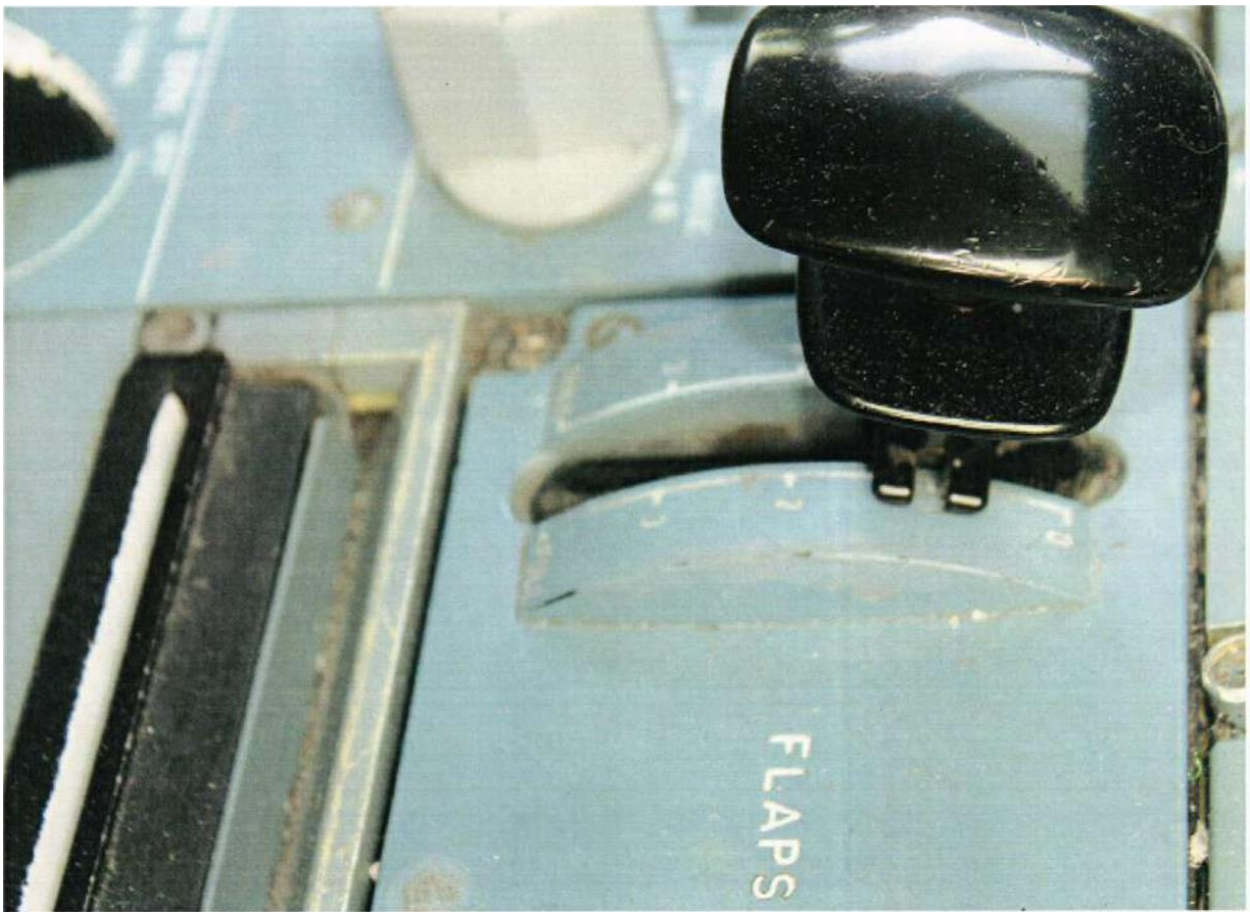



*Figure 25. Position of the flap/slat lever at the accident site*

The landing gear is controlled using a lever located on the front instrument panel. The lever was found in the UP (retracted) position (Fig. 26).

*Figure 26. Position of the landing gear lever at the accident site*

The thrust levers were found in the idle position (Fig. 27).

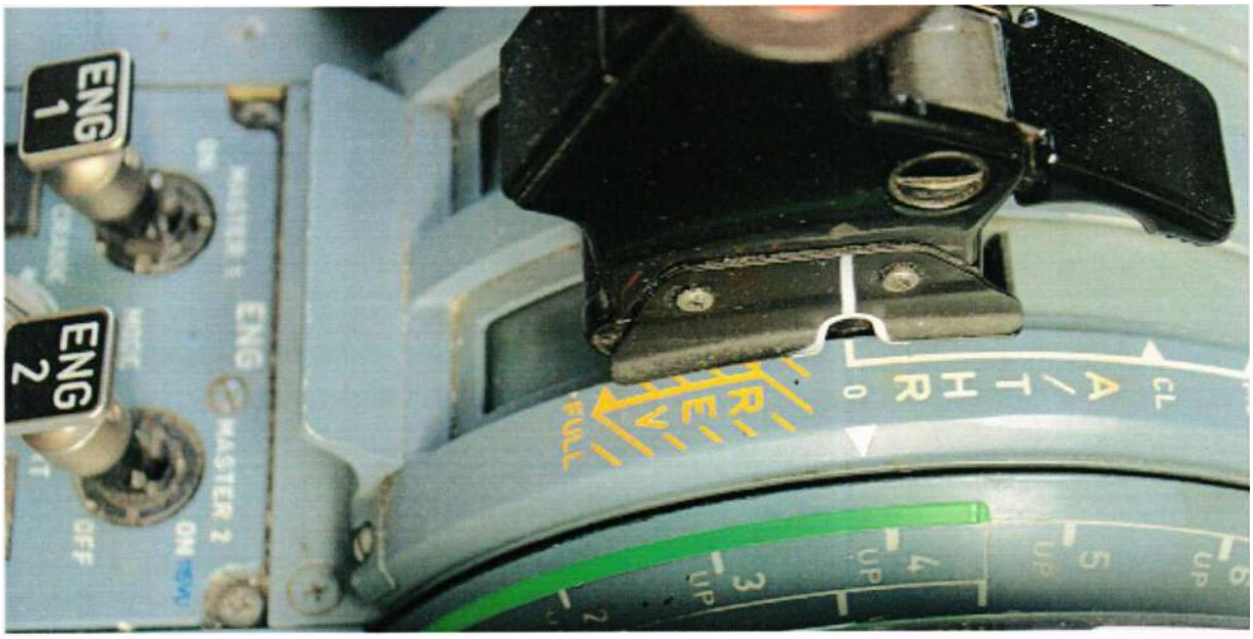



*Figure 27. Position of the thrust levers at the accident site*

### 1.4. Other Damage

Approximately two hectares of corn were damaged.

### 1.5. Crew Information

**Captain**

| | |
|---|---|
| Position | A319/320/321 Captain |
| Name | Yusupov, Damir Kasimovich |
| Gender | Male |
| Age | 42 |
| Education | I. N. Ulyanov Chuvash State University, 2005, diploma No. VSV 1929828, 16/05/2005; major: law, qualification: lawyer<br><br>Saint Petersburg Civil Aviation University, 2013, intermediate professional diploma No. 4/108, 26/07/2013; major: aircraft operation, qualification: pilot<br><br>Grand Marshal B. P. Bugaev Ulyanovsk Civil Aviation Institute, 2018, diploma No. 7226, 26/01/2018; training area: aerial navigation, qualification: bachelor's degree |
| A319/320/321 Training | Ural Civil Aviation Training Center, certificate No. 9615, 26/12/2013 |
| Air Transport Pilot Certificate | Air Transport Pilot Certificate No. 0067697, issued by the Ural ITA of Rosaviatsiia on 07/11/2018 |
| Type Ratings | A319/320/321 aircraft |
| Medical Certificate | 10/04/2019, Ural Airlines Aeromedical Expert Commission first class medical certificate No. 072216, valid until 10/04/2020 |
| Weather Minima | ICAO CAT IIIA, takeoff visibility 150m |
| Total Flight Time | 4,275 h (An-2, A320, A321) |
| Flight Time on A320 and A321 / As Captain | 4,125 h / 824 h |
| Flight Time in the Last 30 Days | 79 h 47 min |
| Flight Time in August 2019 | 35 h 35 min |
| Flight Time in the Last 3 Days | 13 h 44 min |
| Flight Time on the Day of the Accident | ≈ 1 min 30 seconds |

| | |
|---|---|
| Total Duty Time on the Day of the Accident | 1 h 18 min |
| Breaks in Flying During the Last Year | On leave:<br>December 2018 – January 2019, 18 days<br>June 2019, 12 days |
| Date of Last Check of Piloting Skills | 31/07/2019 by an Ural Airlines instructor captain, grade: 5 |
| Emergency Rescue Training—Land | 10/01/2019, Ural Civil Aviation Training Center |
| Emergency Rescue Training—Water | 28/12/2017, Ural Civil Aviation Training Center |
| Simulator Training | 27/05/2019, Ural Airlines |
| Recurrent Training | 14/05/2019 |
| Release for Flight | 29/04/2019 |
| CRM Training | 12/01/2017, certificate No. 148, Ural Civil Aviation Training Center |
| Preliminary Preparation[3] | 26/03/2019 |
| Pre-flight Preparation | 15/08/2019 at Zhukovskiy Airport |
| Crew Rest | More than 19 hours in a hotel |
| Pre-Flight Medical | At the medical office of the Central Flight Staff Clinic, Zhukovskiy Airport, at 01:57 on 15/08/2019 |
| Previous Accidents and Incidents | None |
| Level of English Fluency | ICAO level 4, valid until 26/10/2021 |

In 2013, the Captain[4] graduated from the Buguruslan branch of the St. Petersburg Civil Aviation University with a major in aircraft operations and received his pilot qualification. During his education he flew the An-2 (total flight time: 155 h 31 min), of which 70 h 01 min were spent as PIC. While undergoing training he received Commercial Pilot Third Class certificate No. 004170.

In September 2013, the Captain was hired by the Ural Airlines training group for the position of First Officer. After passing the selection process, he was transferred to the Ural Civil Aviation Training Center, where he spent the period from September to December 2013 completing the A319/320/321 flight crew training program.

On 30/12/2013 he was transferred to the position of First Officer in the Ural Airlines A319/320/321 squadron.

Between 09/01/2014 and 11/01/2014, the Captain completed the following training programs at the Ural Civil Aviation Training Center: human factors training (certificate No. 16); and water emergency training (simulator exercise 13/01/2014). Between 14/01/2014 and 16/01 2014, he completed introductory flight safety training (certificate No. 58). Between 17/01/2014

[3] *Translator's note: The phrase "предварительная подготовка," literally "preliminary preparation/training," is used several times, but I'm unsure of its meaning. It is rendered herein as "preliminary preparation", which is also the translation used in official English translations of other MAK accident reports, but the reader is advised that this translation may be unreliable or misleading.*

[4] In this section, the term "Captain" is also used when discussing those time periods during which the Captain held other positions.

and 20/01/2014, the Captain completed training on the use of RVSM, RNAV, and RNP (PBN) systems (certificate No. 275) and transportation of hazardous goods (certificate No. 149009062, 22/01/2014). Between 27/01/2014 and 28/01/2014 the Captain underwent training on the use of TCAS-II (certificate No. 364).

On 25/01/2014, the Captain completed emergency rescue training.

On 29/01/2014 he was released for flights using RNP10, RNP4, RNAV5, RNAV2, RNAV1, Basic-RNP1, and RNP APCH systems.

On 11/02/2014 the Captain was released for flights within the Moscow terminal control area and within the 25-kilometer zone surrounding border airfields; in conditions of Reduced Vertical Separation Minima in Russia and Eurasia; in the European, Asia-Pacific, and Middle Eastern regions; in the airspace of India and China; and for unsupervised ground handling of A319/320/321 aircraft.

On 17/02/2014, he was released for commissioning as a First Officer on the A319/320/321 aircraft. A break in flights had taken place lasting eight months.

On 10/06/2014, the Captain was released for unsupervised flights as an assigned First Officer on the A319/320/321 aircraft with ICAO CAT III weather minima.

On 24/10/2014, he was released for flights as an unassigned First Officer on the A319/320/321 aircraft.

On 15/05/2015, the Captain was released for flights in the left seat above FL 200.

On 12/01/2017, at the Ural Civil Aviation Training Center, the Captain underwent CRM and human factors training (certificate No. 148, 12/01/2017); between 27/12/2017 and 28/12/2017, water emergency training (certificate No. 9547; between 11/01/2018 and 12/01/2018, hazardous materials training (certificate Ni. 289000006); and between 05/02/2018 and 02/04/2018, training on the safe use of transportation infrastructure (certificate No. 3221).

On 16/03/2018, on the basis of a contest among the First Officers, the Captain was selected as a candidate for commissioning as an aircraft commander on the A319/320/321.

Between 04/04/2018 and 09/04/2018, at the Ural Civil Aviation Training Center, the Captain underwent preparatory command training for First Officers (certificate No. 3316, 09/04/2018).

On 23/05/2018, he was released for commissioning as a probationary Captain (Captain under supervision) on the A319/320/321 aircraft.

On 09/08/2018, his qualification check on the A320 was conducted by the commander of the flight squadron on the Yekaterinburg-Prague-Yekaterinburg route (SVX-PRG-SVX). The result of the check was “grade 5, fit for receipt of line pilot qualification.”

On 17/08/2018, he was appointed to the position of A319/320/321 Captain.

On 20/08/2018, his line pilot certificate, No. 0067460, with an A319/320/321 type rating, was issued by the Ural ITA of Rosaviatsiia.

On 22/08/2018, the Captain was released for visual approaches with circle-to-land on the A319/320/321 aircraft.

Between 24//10/2018 and 26/10/2018, at the Ural Civil Aviation Training Center, the Captain completed training on airman’s English in accordance with ICAO requirements. On 26/10/2018 he completed a qualification check which determined that his English fluency corresponded to ICAO level 4 (report No. 8077/73, 26/10/2018). As a result, on 07/11/2018 his airline pilot certificate was replaced with a new certificate, No. 0067697.

On 20/11/2018, he was released for flights as an unassigned[5] Captain on the A319/320/321 aircraft.

Between 09/01/2019 and 10/01/2019, the Captain completed yearly emergency rescue training for aircraft crewmembers (certificate No. 4, 10/01/2019).

On 27/02/2019 he was approved for ICAO CAT III approaches and landings, and flights with a runway visibility range (RVR) of at least 150 meters, with the following exceptions:

- He did not have the right to approach and land with an RVR of less than 300 meters while operating under ICAO CAT III minimums (lifted 27/05/2019).
- He did not have the right to approach and land with an RVR of less than 450 meters while operating under ICAO CAT II minimums.

On 26/03/2019 he completed spring-summer flight training for the year 2019.

On 17/05/2019, the Captain was approved to fly from the right seat on the A319/320/321.

In May 2019, he underwent recurrent simulator training, including preparatory sessions. The preparatory training included but was not limited to a check of theoretical knowledge, analysis of deferred defects according to the MEL, calculation of takeoff and landing performance, and go/no-go decisions. The theoretical knowledge check included the following topics:

- normal and emergency procedures;
- conduct of flights under special circumstances;
- aircraft equipment and systems;
- approaches and landings under ICAO CAT II and III and takeoffs with a visibility of less than 400 meters;
- recovery from unusual aircraft attitudes, approach to stall, and stall regimes;
- flight under wind shear conditions;
- terrain avoidance maneuvers;
- TCAS response;
- flying as PIC from the right seat.

On 27/05/2019 he underwent a qualification check by a check airman on the simulator, which included but was not limited to rejected takeoffs, engine failure after $V_1$ (before $V_2$), approach and landing with inoperative engine(s) without autopilot or autothrottle, terrain avoidance maneuvers, and emergency evacuations. The pilot received a grade of 5 and was declared to have "met the qualification requirements of an airline pilot."

On 19/03/2018, Rosaviatsiia issued order No. 210-17 entitled, "Concerning efforts to improve the quality of inspections of organizations carrying out professional training of aviation personnel for Russian civil aircraft operators conducting scheduled operations." The order recommended that aviation training centers and operators engaged in scheduled operations implement changes to their flight crew training programs in order to ensure that recurrent training on the following topics was carried out no less than once per 12-month period:

[5] Translator's note: This appears to mean that he did not have a fixed base, but the meaning in this context is not completely certain.

- theoretical and practical training on unusual attitude recovery, approach to stall, and stall recovery;
- simulator training on all non-emergency system failures, including an examination;
- theoretical and practical training on crew resource management.

At Ural Airlines, the above recommendations were not complied with, and the airline did not provide the Captain with theoretical training on crew resource management in 2018 (after the receipt of Rosaviatsiia order No. 210-17, 19/03/2018).[6] The Captain underwent the aforementioned CRM training on 12/01/2017.

**Use of Time Off**

Between 13/01/2018 and 28/01/2018, the Captain was granted part of his additional paid leave for work under special circumstances amounting to 13 calendar days, and part of his yearly basic paid leave amounting to 3 calendar days.

Between 14/04/2018 and 23/04/2018, the Captain was granted part of his basic paid leave amounting to 10 calendar days.

Between 22/12/2018 and 23/04/2018, the Captain was granted part of his basic paid leave amounting to 10 calendar days.

Between 23/06/2019 and 04/07/2019, he was granted part of his past paid leave amounting to 5 calendar days, and part of his additional paid leave for work under special circumstances amounting to 7 days.

In 2019, basic and additional paid time off was planned between 01/01/2019 and 12/01/2019, between 23/02/2019 and 10/03/2019, between 1/04/2019 and 20/04/2019, and between 01/11/2019 and 22/11/2019. The issuance of time off during an unplanned period was carried out on the Captain's request.

By 13/11/2019, the Captain's unused basic and additional leave for the working period from 30/12/2017 to 15/08/2019 amounted to 96 calendar days.

***Note:*** *The following data were received from the head of the Ural Airlines personnel department by letter No. 4.2-319 on 13/11/2019:*

| *Information about Captain (Name) – A319/320/321 aircraft commander* | | |
|---|---|---|
| *Leave (in calendar days) on 15/08/2019* | | |
| *Working period* | *Basic* | *Additional (for work under special circumstances)* |
| *30/12/2017 – 30/12/2018* | | *35* |
| *By 13/11/2019* | | |
| *30/12/2018 – 30/12/2019*[7] | *19* | *42* |

**First Officer**

[6] According to information provided by the airline, changes were made to part D of the FOM during the investigation, calling for CRM training once in every 12-month period.

[7] By the end of the present work period (30/12/2019) the pilot had planned for an additional 22 days of leave.

| | |
|---|---|
| Position | A319/320/321 First Officer |
| Name | Murzin, Georgii Aleksandrovich |
| Gender | Male |
| Age | 23 |
| Education | Saint Petersburg Civil Aviation University, 2017, intermediate professional diploma No. 4/275, 28/07/2017; major: aircraft operation, qualification: pilot |
| A319/320/321 Training | Ural Civil Aviation Training Center, certificate No. 6362, 29/08/2018 |
| Air Transport Pilot Certificate | Air Transport Pilot Certificate No. 0067505, issued by the Ural ITA of Rosaviatsiia on 06/09/2018 |
| Type Ratings | A319/320/321 aircraft Co-pilot. Approved for IFR operations. |
| Medical Certificate | 23/05/2019, Ural Airlines Aeromedical Expert Commission first class medical certificate No. 072331, valid until 23/05/2020 |
| Weather Minima | ICAO CAT IIIA, takeoff visibility 150m |
| Total Flight Time | 780 h (Diamond DA 40 NG, DA 42 NG, A320, A321) |
| Flight Time on A319/320/321 | 624 h |
| Flight Time in August 2019 | 34 h 09 min |
| Flight Time in the Last 3 Days | 13 h 44 min |
| Flight Time on the Day of the Accident | ≈ 1 min 30 seconds |
| Total Duty Time on the Day of the Accident | 1 h 15 min |
| Breaks in Flying During the Last Year | None |
| Date of Last Check of Piloting Skills | 31/07/2019 by an Ural Airlines deputy instructor captain, grade: 4 |
| Emergency Rescue Training—Land | 18/06/2019, Ural Civil Aviation Training Center |
| Emergency Rescue Training—Water | 04/07/2018, Ural Civil Aviation Training Center |
| Simulator Training | 08/03/2019, Ural Airlines |
| Recurrent Training | 04/10/2019 |
| Release for Flight | 29/04/2019 |
| CRM Training | 12/07/2018, certificate No. 5960, Ural Civil Aviation Training Center |
| Preliminary Preparation | 29/03/2019 |
| Pre-flight Preparation | 15/08/2019 at Zhukovskiy Airport under direction of the Captain |
| Crew Rest | More than 19 hours in a hotel |

| | |
|---|---|
| Pre-Flight Medical | At the medical office of the Central Flight Staff Clinic, Zhukovskiy Airport, at 02:00 on 15/08/2019 |
| Previous Accidents and Incidents | None |
| Level of English Fluency | ICAO level 4, valid until 16/12/2020 |

In 2017, the First Officer graduated from the Buguruslan branch of the St. Petersburg Civil Aviation University with a major in aircraft operations and received his pilot qualification. During his education he flew the Diamond DA 40 NG (total flight time: 130 h 39 min) and the Diamond DA 42 NG (total flight time: 25 h 39 min), of which 86 h 04 min were spent as PIC. While undergoing training he received Commerical Pilot Third Class certificate No. 0050755, issued by the Volga ITA of Rosaviatsiia on 16/06/2017, with qualifications for airplane single engine land, airplane multi-engine land, and instrument airplane.

Between 10/07/2017 and 29/09/2017, he underwent training at the Ural Civil Aviation Training Center under the supplementary professional program "English language training for flight crews conducting international flights" (certificate No. 8054, 29/09/2017). On 16/12/2017 he completed a qualification check which determined that his English fluency corresponded to ICAO level 4 (report No. 9253/2939, 16/12/2017).

Between 30/01/2018 and 13/02/2018, the First Officer underwent training at the "Comp Lang" Training Center under the program "Enhancement of qualifications for civil flight crews conducting international flights" (certificate No. 1079-18, 13/02/2018).

In June 2018, he was hired by the Ural Airlines training group for the position of First Officer. After passing the selection process, he was transferred to the Ural Civil Aviation Training Center, where he spent the period from 04/06/2018 to 29/08/2018 completing the A319/320/321 flight crew training program. During his training he completed courses on the transportation of hazardous goods (certificate No. 289001073, 16/07/2018); on-ground emergencies (certificate No. 5765, 02/07/2018); water emergencies (certificate No. 5869, 06/07/2018); and introductory human factors training (certificate Ni. 5960, 12/07/2018). Having completed this training, he received commercial pilot certificate No. 0067505, issued by the Ural ITA of Rosaviatsiia on 06/09/2018, with ratings for "A319/320/321 copilot" and "instrument airplane."

On 05/09/2018 he was released for flights using RNP10, RNP4, RNAV5, RNAV2, RNAV1, Basic-RNP1, and RNP APCH systems.

On 10/09/2018 he was released for flights in conditions of Reduced Vertical Separation Minima in Russia and Eurasia; in European, Asia-Pacific, and Middle Eastern regions; and in the airspace of India and China.

On 11/09/2018 he was released for flights within the Moscow terminal control area and within the 25-kilometer zone surrounding border airfields.

On 13/09/2018 he was authorized for unsupervised ground handling of A319/320/321 aircraft.

On 02/10/2018 he was appointed to the position of First Officer in the Ural Airlines A319/320/321 flight squadron. On 03/10/2018 he was released for commissioning as a First Officer on the A319/320/321. A break in flights had taken place lasting one year and two months.

On 10/10/2018 he completed training for the fall-winter period of 2018-2019.

On 31/12/2018 he completed a check of piloting and navigation skills for unsupervised flights, international flights, and affirmation of qualifications. The Ural Airlines examiner concluded that he "may carry out flights as a First Officer on the A319/320/321 aircraft, including international flights, as a limited crewmember, and in ICAO CAT III conditions. Meets the requirements of his commercial pilot certificate."

On 09/01/2019, by order No. 5 of the flight squadron commander, he was released for unsupervised flights as a First Officer on the A319/320/321 aircraft as an assigned crewmember (with a different Captain) in ICAO CAT III weather minima. On 09/08/2019, for reasons of commercial necessity, the First Officer was assigned to the accident Captain, a fact which was noted in the crew roster of the flight squadron under the signature of the flight squadron commander. The airline's documents did not provide for further preliminary preparation. In response to an inquiry by the Commission, Ural Airlines replied that "at the moment of the incident, the First Officer was carrying out the flight as an assigned crewmember. A copy of the relevant page from the crew roster of the flight squadron is attached. The crew was formed on 09/08/19. According to the procedures in place at that time, the initial formation of a crew upon the Captain's release for unsupervised work is determined by order of the flight squadron commander, and further changes to the crew roster are confirmed by the flight squadron commander's signature in the corresponding column."

According to the preliminary training records of the flight squadron, the Captain's preliminary preparation[8] was conducted on 26/03/2019, and the First Officer's on 29/03/2019.

On 28/02/2019, the First Officer underwent recurrent similar training, which included preliminary preparation. The preliminary preparation included, among other things, a check of theoretical knowledge, analysis of deferred defects according to the MEL, calculation of takeoff and landing performance, and go/no-go decisions. The theoretical knowledge check included the following topics:

- normal and emergency procedures;
- conduct of flights under special circumstances;
- aircraft equipment and systems;
- approaches and landings under ICAO CAT II and III and takeoffs with a visibility of less than 400 meters;
- recovery from unusual aircraft attitudes, approach to stall, and stall regimes;
- flight under wind shear conditions;
- terrain avoidance maneuvers;
- TCAS response.

On 08/03/2019 he underwent a qualification check by the flight squadron commander on the simulator, which included but was not limited to rejected takeoffs, engine failure after $V_1$ (before $V_2$), approach and landing with inoperative engine(s) without autopilot or autothrottle, terrain avoidance maneuvers, and emergency evacuations. The pilot received a grade of 4 and was declared to have "met the qualification requirements of an airline pilot."

On 29/04/2019, the First Officer completed training for the 2019 fall-winter period.

On 18/06/2019, at the Ural Civil Aviation Training Center, he completed annual emergency rescue training (certificate No. 5909, 18/06/2019).

[8] Translator's note: It's still unclear precisely what kind of activity is meant by "preliminary preparation."

**Use of Time Off**

From the time of his appointment to the position of First Officer in the Ural Airlines A319/320/21 flight squadron (02/10/2018) until 15/08/2019 (the day of the accident), the First Officer was never on leave. In 2019, basic and additional paid leave had been planned for him between 25/08/2019 and 28/09/2019, and between 25/11/2019 and 28/12/2019.

**Cabin Crew**

| | |
|---|---|
| Position | Airbus A319/320/321 flight attendant |
| Name | Vershinina, Nadezhda Pavlovna |
| Gender | Female |
| Age | 25 |
| Education | Technical College |
| Retraining on A321 | 10/05/2017 – 24/07/2017 at the Ural Civil Aviation Training Center under the program "Introductory training for flight attendants on the A319/320/321 aircraft at domestic and international airlines." |
| Flight Attendant Certificate, Term of Validity | No. 00021968, issued by the Ural ITA of Rosaviatsiia on 03/08/2017, unlimited |
| Active Aircraft Type Rating | A319/320/321, 29/08/2017 |
| Recurrent Training | 10/07/2019 |
| Check Flight on the A321 | 21/04/2019, Ural Airlines, grade: 4 |
| Emergency Rescue Training - Water | 05/07/2019, Ural Civil Aviation Training Center |
| Emergency Rescue Training - Land | 04/07/2019, Ural Civil Aviation Training Center |
| Release for Flights in Fall/Winter | Directive 6.2.46, 11/04/2019 |
| Medical Certificate | 26/04/2017, Ural Airlines medical service, medical certificate second class RA No. 195145, valid until 06/04/2022 |
| Total Flight Time | 1,570 h 1 min |
| Flight Time on the A319/320/321 | 1,570 h 1 min |
| Flight Time in the Last Month | 76 h 07 min |
| Flight Time on the Day of the Accident | ≈ 01 min 30 s |
| Rest Before the Flight | 19 hours in a hotel |
| Total Duty Time on the Day of the Accident | 01 h 33 min |

| | |
|---|---|
| Pre-Flight Medical | At the medical office of the Central Flight Staff Clinic, Zhukovskiy Airport, at 01:42 on 15/08/2019 |
| Previous Accidents and Incidents | None |

According to work agreement No. 557/L, 17/07/2017, and order No. 557 of the Ural Airlines general director, 17/07/2017, she was hired by the Flight Director Subdivision of Ural Airlines for the position of flight attendant.

| | |
|---|---|
| Position | Airbus A319/320/321 flight attendant |
| Name | Yagodina, Yana Igorevna |
| Gender | Female |
| Age | 24 |
| Education | University |
| Retraining on A321 | 09/01/2018 – 30/03/2018 at the Ural Civil Aviation Training Center under the program "Introductory training for flight attendants on the A319/320/321 aircraft at domestic and international airlines." |
| Flight Attendant Certificate, Term of Validity | No. 00067186, issued by the Ural ITA of Rosaviatsiia on 19/04/2018, unlimited |
| Active Aircraft Type Rating | A319/320/321, 12/06/2018 |
| Recurrent Training | 19/03/2019 |
| Check Flight on the A321 | 02/06/2019, Ural Airlines, grade: 4 |
| Emergency Rescue Training - Water | 21/03/2018, Ural Civil Aviation Training Center |
| Emergency Rescue Training - Land | 19/03/2019, Ural Civil Aviation Training Center |
| Release for Flights in Fall/Winter | Directive 6.2.46, 11/04/2019 |
| Medical Certificate | 11/02/2017, Ural Airlines medical service, medical certificate second class RA No. 195145, valid until 11/12/2022 |
| Total Flight Time | 1,027 h 15 min |
| Flight Time on the A319/320/321 | 1,027 h 15 min |
| Flight Time in the Last Month | 89 h 40 min |
| Flight Time on the Day of the Accident | ≈ 01 min 30 s |
| Rest Before the Flight | 19 hours in a hotel |
| Total Duty Time on the Day of the Accident | 01 h 27 min |
| Pre-Flight Medical | At the medical office of the Central Flight Staff Clinic, Zhukovskiy Airport, at 01:48 on 15/08/2019 |
| Previous Accidents and Incidents | None |

According to work agreement No. 320/L, 17/04/2018, and order No. 320 of the Ural Airlines general director, 17/04/2018, she was hired by the Flight Director Subdivision of Ural Airlines for the position of flight attendant.

| | |
|---|---|
| Position | Airbus A319/320/321 flight attendant |
| Name | Sliakaeva, Aliia Maratovna |
| Gender | Female |
| Age | 27 |
| Education | University |
| Retraining on A321 | 11/12/2017 – 03/03/2018 at the Ural Civil Aviation Training Center under the program "Introductory training for flight attendants on the A319/320/321 aircraft at domestic and international airlines." |
| Flight Attendant Certificate, Term of Validity | No. 00067058, issued by the Ural ITA of Rosaviatsiia on 15/03/2018, unlimited |
| Active Aircraft Type Rating | A319/320/321, 23/04/2018 |
| Recurrent Training | 14/02/2019 |
| Check Flight on the A321 | 23/06/2019, Ural Airlines, grade: 4 |
| Emergency Rescue Training - Water | 12/02/2018, Ural Civil Aviation Training Center |
| Emergency Rescue Training - Land | 14/02/2019, Ural Civil Aviation Training Center |
| Release for Flights in Fall/Winter | Directive 6.2.46, 11/04/2019 |
| Medical Certificate | 31/08/2017, Ural Airlines medical service, medical certificate second class RA No. 195145, valid until 31/08/2022 |
| Total Flight Time | 1,169 h 09 min |
| Flight Time on the A319/320/321 | 1,169 h 09 min |
| Flight Time in the Last Month | 88 h 28 min |
| Flight Time on the Day of the Accident | ≈ 01 min 30 s |
| Rest Before the Flight | 19 hours in a hotel |
| Total Duty Time on the Day of the Accident | 01 h 30 min |
| Pre-Flight Medical | At the medical office of the Central Flight Staff Clinic, Zhukovskiy Airport, at 01:45 on 15/08/2019 |
| Previous Accidents and Incidents | None |

According to work agreement No. 130/L, 01/03/2018, and order No. 130 of the Ural Airlines general director, 01/03/2018, she was hired by the Flight Director Subdivision of Ural Airlines for the position of flight attendant.

| | |
|---|---|
| Position | Airbus A319/320/321 flight attendant |
| Name | Goncharenko, Dmitrii Nikolaevich |

| | |
|---|---|
| Gender | Male |
| Age | 27 |
| Education | Intermediate |
| Retraining on A321 | 09/01/2018 – 31/03/2018 at the Ural Civil Aviation Training Center under the program "Introductory training for flight attendants on the A319/320/321 aircraft at domestic and international airlines." |
| Flight Attendant Certificate, Term of Validity | No. 00067172, issued by the Ural ITA of Rosaviatsiia on 16/04/2018, unlimited |
| Active Aircraft Type Rating | A319/320/321, 07/06/2018 |
| Recurrent Training | 20/03/2019 |
| Check Flight on the A321 | 02/06/2019, Ural Airlines, grade: 4 |
| Emergency Rescue Training - Water | 21/03/2018, Ural Civil Aviation Training Center |
| Emergency Rescue Training - Land | 19/03/2019, Ural Civil Aviation Training Center |
| Release for Flights in Fall/Winter | Directive 6.2.46, 11/04/2019 |
| Medical Certificate | 04/12/2017, Ural Airlines medical service, medical certificate second class RA No. 195145, valid until 04/12/2022 |
| Total Flight Time | 1,114 h 27 min |
| Flight Time on the A319/320/321 | 1,114 h 27 min |
| Flight Time in the Last Month | 85 h 45 min |
| Flight Time on the Day of the Accident | ≈ 01 min 30 s |
| Rest Before the Flight | 19 hours in a hotel |
| Total Duty Time on the Day of the Accident | 01 h 24 min |
| Pre-Flight Medical | At the medical office of the Central Flight Staff Clinic, Zhukovskiy Airport, at 01:51 on 15/08/2019 |
| Previous Accidents and Incidents | None |

According to work agreement No. 304/L, 03/04/2018, and order No. 304 of the Ural Airlines general director, 03/04/2018, he was hired by the Flight Director Subdivision of Ural Airlines for the position of flight attendant.

## 1.6. Aircraft Information

*Figure 28. A321-211 aircraft VQ-BOZ before the accident*

| | |
|---|---|
| Aircraft Type | A321-211 |
| Manufacturer | Airbus Industry [sic] |
| Data of Manufacture | 31/03/2004 |
| Serial Number | 2117 |
| Registration Number | VQ-BOZ |
| Certificate of Registration | No. 2806, 30/04/2017, issued by the Bermuda Civil Aviation Authority (BCAA) |
| Lessor | Leasing company: ACG Aircraft Leasing Ireland Limited |
| Certificate of Airworthiness | No. 1651, 26/10/2018, issued by the Bermuda Civil Aviation Authority (BCAA), valid under 08/11/2019 |
| Service Life / Life Limit | Not established |
| Total Operating Time | 48,980 h, 20,132 cycles |
| Service Life Between Overhauls | Not established |
| Last Scheduled Maintenance | 27/04/2019 at Ural Airlines, a C-check was carried out on the aircraft (Customer Work |

| | |
|---|---|
| | Order CWO B000030), letter No. PP00017131 |
| Last Line Maintenance | 14/08/2019 at Zhukovskiy Airport, a Daily Check was carried out on the aircraft by FL Technic specialists (work order No. OZD283Aug, 14/08/2019). |

The aircraft was fitted with CFM-56-5B type engines produced by CFM and a Honeywell GTCP 131-9A type APU.

| Engine | No. 1 | No. 2 | APU |
|---|---|---|---|
| Type | CFM56-5B3/P | CFM56-5B3/3 | GTCP 131-9(A) |
| Serial Number | 575728 | 697747 | P-3669 |
| Data of Manufacture | 07/11/2003 | 21/03/2008 | 23/07/2007 |
| Service Life / Life Limit | Not established | Not established | Not established |
| Total Operating Time (Hours / Cycles) | 47,563.95 / 19,684 | 18,646.27 / 8366 | 16,228 / 14,297 |
| Number of Overhauls | 2 | 1 | 2 |
| Data and Location of Last Overhaul | 13/03/2018, S7 Engineering, Moscow | 26/03/2015, General Electric Aircraft Engine Service, United Kingdom | 11/09/2014, Chase Aerospace, New Zealand |
| Total Time Since Last Overhaul (Hours / Cycles) | 6,275 / 1,929 | 11,828 / 3,997 | 8,128 / 7,640 |

**Aircraft Maintenance**

All scheduled and line maintenance work on the aircraft was carried out by Ural Airlines' personnel and contract organizations in accordance with the applicable aircraft maintenance agreements.

In accordance with the certificates of the maintenance organizations—No. BDA/AMO/357, 22/01/2019, issued by the Bermuda Civil Aviation Authority (BCAA); and No. EASA.145.0415, 12/11/2015, issued by the European Aviation Safety Agency (EASA)—Ural Airlines was permitted to carry out scheduled and line maintenance on Airbus A319/320/321 aircraft.

The Ural Airlines Maintenance Organization Manual (U6MNT2-2-01, 05/07/2019) was approved by order No. 109 of the Ural Airlines general director on 18/07/2019 and accepted by the Ural ITA of Rosaviatsiia and the Bermuda Civil Aviation Authority on 11/07/2019.

Maintenance of the aircraft was carried out under Ural Airlines Aircraft Maintenance Program MP SVR A319/320/321, Revision 32, 03/06/2019 (henceforth referred to as the Maintenance Program), which was approved by the Bermuda Civil Aviation Authority on 11/06/2019.

**Scheduled Maintenance**

According to section 2.3 of the Maintenance Program, a C-check consists of maintenance tasks with an interval of 12,000 flight hours, 8,000 cycles, and/or 24 months.

Scheduled maintenance of the aircraft under C-check form PP00017131 was carried out between 09/04/2019 and 27/04/2019, at which time the aircraft had 47,417 flight hours and 19,650 cycles. During the C-check, 600 tasks were carried out in accordance with C-check form PP00017131, and the No. 2 engine was replaced. A leased engine, No. ESN 697747, was installed in place of the removed engine, No. ESN 575729, which had been sent for a scheduled overhaul.

**Line Maintenance**

According to section 2.3 of the Maintenance Program, "DAILY" maintenance must be carried out once every 60 hours on any operational aircraft.

According to section 3.3 of the Maintenance Program, an 8-day check must be carried out once every 8 calendar days on any operational aircraft.

According to section 2.3 of the Maintenance Program, an A-check must be carried out once every 750 flight hours, 750 cycles, or 4 months, on any operational aircraft.

On 06/06/2019, an A04-check under form PP00018267 was carried out, at which time the aircraft had 48,389 flight hours and 19,944 cycles. During the A04-check, 132 tasks were carried out in accordance with form PP00018267.

On 08/08/2019, an 8-day (weekly) check under form PP00018537 was carried out, at which time the aircraft had 48,869 flight hours and 20,096 cycles. During the 8-day check, 40 tasks were carried out in accordance with form PP00018537.

A Daily check was carried out on 14/08/2019 under form No. 283, at which time the aircraft had 48,967 flight hours and 20,128 cycles.

Comments on the completion of the work and the inspection of its execution were included in the attachments to the work documentation.

Prior to its last flight on 15/08/2019, a transit check was carried out on the aircraft at Zhukovsiy Airport. The post-flight and pre-flight inspections were carried out by the crew in accordance with the FCOM and registered in the technical log.

On 15/08/2019, flights were carried out with the following deferred defects under the MEL:

| No. | Date Opened | Grace Period | Category | Description |
|---|---|---|---|---|
| 1 | 07/08/2019 | 90 days | D | PRINTER INOP |
| 2 | 09/08/2019 | 10 days | C | SEAT 6C: BACKREST SECURED IN THE UPRIGHT POSITION AND AFFECTED SEAT OPERATIVE |

Since 09/08/2019, a defect had been deferred in accordance with MEL section 25-20-02A CATEGORY C, concerning the position of the backrest of passenger seat 6C. According to the

defect description, the seat could carry a passenger as long as the backrest was fixed in the upright position and the reclining mechanism was deactivated. This measure was taken.

### 1.7. Meteorological Information

The general situation in Moscow Oblast' and at Ramenskoe Airport on 15/08/2019 was characterized by a cyclonic trough centered in the Tver' region, through which a frontal occlusion was passing, oriented from northwest to southeast. The frontal occlusion passed over the area of Ramenskoe Airport between 00:26 and 01:30, causing thunderstorm activity with rainfall on the airport and in its vicinity. By the time of the accident, the front had moved to the northeast of Ramenskoe Airport.

At 01:48, during their self-directed briefing at Zhukovskiy International Airport, the crew received their flight documentation, including meteorological information from the Rosgidrometa Main Aviation Meteorological Center's automated pre-flight information system. This information consisted of a terminal airport forecast (TAF) valid for the period between 00:00 and 24:00; the 01:30 METARs for their departure, alternate, and destination airports; a SIGMET 1 for the Moscow FIR, valid from 02:00 to 05:00; maps of the forecast weather conditions at flight levels 250-360 in the Eurasia region from the Global Forecast Center in London, produced at 06:00 on 15/08/2019; and maps of wind and temperatures at flight level 340 in the Eurasia region, also from the Global Forecast Center in London, produced at 03:00 and 06:00, respectively, on 15/08/2019.

The active TAF for Ramenskoe Airport at the moment of the accident was issued by the meteorologist on duty at 01:56 and was valid for the period between 03:00 on 15/08/2019 and 03:00 on 16/08/2019.

*Surface wind 120˚ at 5 m/s, visibility more than 10 km, broken clouds, cloud base 900 m above ground level, maximum temperature +24˚C at 12:00 on 15/08/2019, minimum temperature +15˚C at 03:00 on 15/08/2019; for the period between 03:00 and 09:00 on 15/08/2019, surface wind 180˚ at 5 m/s, between 09:00 ad 11:00 on 15/08/2019 gradually shifting to 320˚ at 6 m/s, between 17:00 and 19:00 on 15/08/2019 gradually shifting to 020˚ at 3 m/s.*

*Regular weather report for Ramenskoe Airport at 03:00 on 15/08/2019: wind 100˚ at 4 m/s, visibility 10 km, broken stratocumulus, cloud base 1,590 m above ground level; air temperature +15.4˚C, dew point +14.1˚C, humidity 92%, pressure: QFE 746.3 mmHg, QNH 1008.7 hPa.*

After the accident, a weather request was not sent to the airport meteorologist upon activation of the emergency alarm.

An irregular weather observation, conducted at Ramenskoe Airport at 03:17, was carried out by the airport meteorologist after the alarm sounded: *wind 110˚ at 5 m/s, visibility 10 km, broken stratocumulus, cloud base 1,590 m above ground level, significant mid-level overcast at 2000 m above ground level, air temperature +15.6˚C, dew point +14.3˚C, humidity 92%, pressure: QFE 746.3 mmHg, QNH 1008.5 hPa.*

The meteorological conditions had no effect on the flight.

### 1.8. Navigational Aids, Landing Aids, and ATC

At the time of the accident, several radionavigational devices were available at the airport, including a "Lira-A" airport radar system; an SP-200.1 localizer aligned to 301˚ magnetic; an SP-200.1 glide slope aligned to 301˚ magnetic; two ARP-95 VORs, serial numbers 0008 and 1066; an outer NDB along 301˚ magnetic; an outer NDB along 121˚ magnetic; and an inner NDB along 301˚ magnetic.

No comments had been made regarding the functional of the radionavigational equipment, no signs of failure or degradation were detected, the crew did not complain of any problems with the equipment before or after the accident, and at no time was the equipment operated on backup power.

The functioning of the radionavigational equipment met regulatory standards. No comments on its functionality were submitted by the controllers.

### 1.9. Means of Communication

At the time of the accident, several means of communication were available at the airport, including a radio transmitting center (with a Fazan 19P50 transmitter and a Fazan 19R50 transceiver); a radio receiving center (with a Fazan 19PRM receiver); a Kamerton voice switching system; a backup Fazan 19R5 radio transceiver; an Armtel emergency notification system; a SMAR-T multi-channel automatic registration system; and an ET-MTsM (P600 MTsM) multi-channel digital tape recorder.

All mobile and fixed means of radio communication at the airport were working properly. No comments concerning their functionality had been lodged by controllers or flight crews.

The A321 VQ-BOZ was equipped with three VHF/COM transceivers and one HF transceiver.

During engine start and taxi, the crew maintained communication with the ground controller using the VHF transceiver on a frequency of 131.0 MHz, and thereafter maintained communication with the departure controller using the VHF transceiver on a frequency of 125.250 MHz. The radio connection was stable.

The functioning of the means of communication had no effect on the flight.

### 1.10. Airport Information

Ramenskoe Airport is a Class A joint-base airport. On 10/08/2007, by directive No. 1034-r of the government of the Russian Federation, it was included in the List of Russian Joint-Base Airports" as a joint base for Russian Ministry of Industry and Trade experimental aviation, the Russian Defense Ministry, the Russian Ministry of Emergency Situations' Emergency Rescue Team, Aviastar-TU, Alrosa Avia, and the V. S. Grizodubovaia Aviation Company.

The airport is located 1 km south of the town of Zhukovskiy and 3 km west of the town of Ramenskoe. The official geographic coordinates of the airport are 55˚33'10.30" N, 038˚08'59.30" E. Its height above sea level is +115 m. The maximum height of the airport is

+123 m. The average magnetic declination is +10˚49’. The local time is UTC +3. The coordinate system in use is PZ-90.02.

The airport allows both visual and instrument flights.

The airport possesses[9] state airport registration No. 96-S, 30/11/2015, and state experimental airport registration No. 10, 31/05/2018.

Ramenskoe Airport is a hub airport equipped for international flights. The airport is open 24 hours a day provided that weather minima are met.

Ramenskoe Airport’s ICAO airport code is UUBW and its IATA airport code is ZIA.

The general director of the M. M. Gromov Flight Institute is the managing operator of the airport.

The airport property forms an irregular polygon measuring 6.0 x 2.5 km.

The dirt portion of the airfield consists of a layer of turf covered by mixed grass, 20 cm thick, on top of an alluvial sand base. This base consists of sandy soil with a bulk density of 1.5-1.6 kg/cm$^2$. The density of the soil itself is 2.7 kg/cm$^2$. The dirt portion of the airfield is not designed for aircraft movements in any season, except for the dirt runway.

The runway area and the adjoining airport buildings to the north, west, and southwest are fenced off and guarded 24/7.

The airport has two paved runways (Fig. 29), runway 12/30, and runway 08/26; a dirt runway[10] with a grass surface; a network of taxiways; aircraft parking areas for locally based organizations; and parking areas for commercial aircraft.

[9] See also section 1.18.8 of this report.

[10] Runway 08/26 and dirt runway 12/30 are not available for commercial flights.

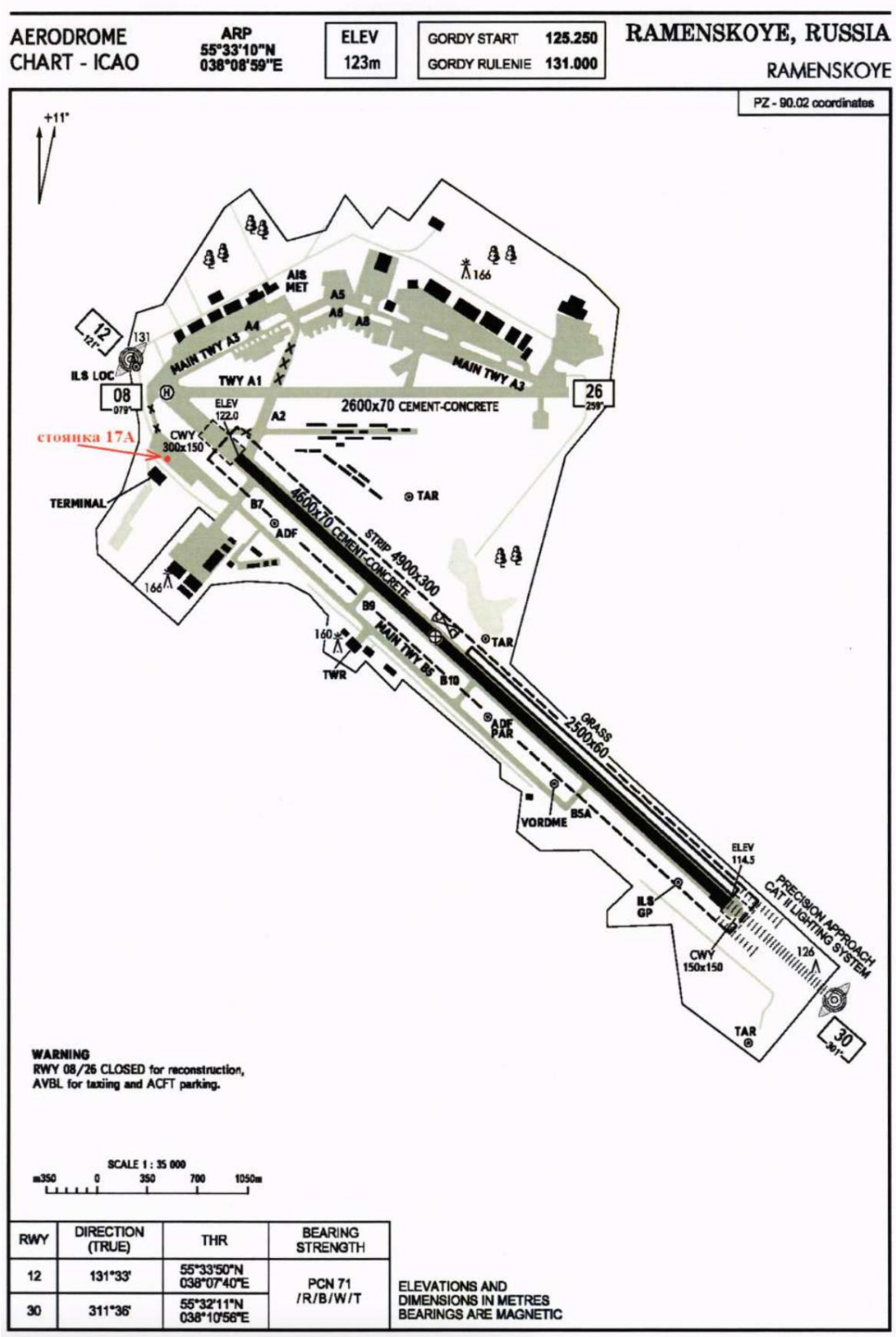



*Figure 29. Ramenskoe aerodrome chart (the parking space of the accident aircraft is indicated with an arrow)*

Runway 12/30 is a Class A runway. Its dimensions are 4600m x 70m. Runway 12 has a magnetic heading of 120˚44’ and a true heading of 131˚33’29”, while Runway 30 has a magnetic heading of 300˚47’ and a true heading of 311˚36’11”. Its carrying capacity is 71/R/B/W/T and the runway surface is made from concrete with a thickness of 65-80 cm. The coordinates of the threshold of Runway 12 are 55˚33’50.14” N, 038˚07’39.95” E, and the threshold elevation is 122.2 meters above sea level. The coordinates of the threshold of Runway 30 are 55˚32’11.42” N, 038˚10’56.23 E, and the threshold elevation is 114.5 meters above sea level.

Available distances (in meters) for these runways are shown in the table below.

| Runway | Available Runup Distance | Available Takeoff Distance | Available Rejected Takeoff Distance | Available Landing Distance | Overrun Area |
|---|---|---|---|---|---|
| 12 | 4,600 | 4,750 | 4,600 | 4,600 | 150 |
| 30 | 4,600 | 4,900 | 4,600 | 4,600 | 300 |

Clear areas extend for a distance of 150 meters beyond the threshold of Runway 12 and 150 meters beyond the threshold of Runway 30. There are also clear areas extending 150 meters from the runway axis on both sides.

The paved area before the threshold of Runway 30 measures 75 x 60 m and has a pavement thickness of 40 cm. The paved area before the threshold of Runway 12 measures 80 x 70 m and has a pavement thickness of 80 cm.

There are no paved overrun areas. Side overrun areas extend for 125 meters from both sides of the runway.

An emergency hydraulic braking system is installed beyond the paved area leading up to the threshold of Runway 12. It is always in operation and is raised five meters above the level of the runway.

Runway 12/30 has standard day/night threshold markings, edge markings, touchdown zone markings, fixed distance markings, centerline markings, and start lines. Runway 12 is equipped with an OVI-1 type centerline lighting system, without approach lights. Runway 30 has an OVI-2 type lighting system.

The supplement to the flight planning instructions for flights in the vicinity of Ramenskoe Airport, entitled “Flight Planning for Civilian Flights,” was approved by the head of the M. M. Gromov Flight Institute and was registered with the Central ITA of Rosaviatsiia on 27/06/2011, No. TsM1-77.

### 1.11. Flight Recorders

A321 VQ-BOZ was equipped with the following flight recorders:

- A Honeywell 980-4700-042 Solid-State Flight Data Recorder
- A Honeywell 980-6022-001 Solid-State Cockpit Voice Recorder
- A Teledyne 2234320-01-01 Flight Data Interface Management Unit

These flight recorders were found at the accident site in the following conditions.

The Honeywell 980-4700-042 Solid-State Flight Data Recorder, serial No. 6952 (Fig. 30) was found on initial inspection to be in good condition and was not damaged in any way.

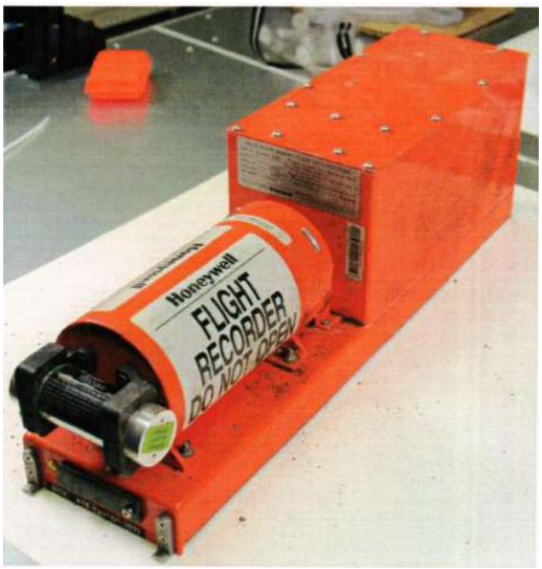



*Figure 30. Honeywell 980-4700-042 Solid State Flight Data Recorder*

The Honeywell 980-6022-001 Solid State Cockpit Voice Recorder, serial No. CVR120-05556 (Fig. 31) was found on initial inspection to be in good condition and was not damaged in any way.

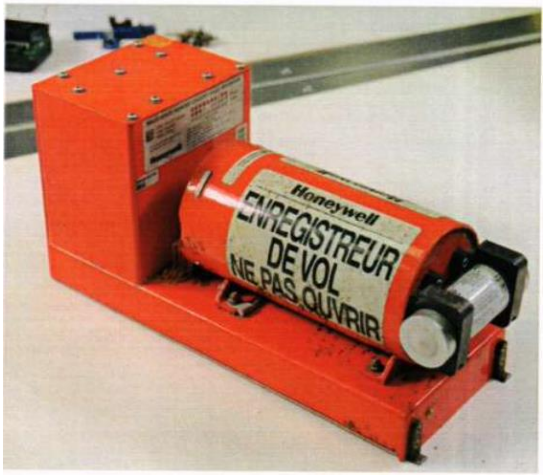



*Figure 31. Honeywell 980-6022-001 Solid State Cockpit Voice Recorder*

The Teledyne 2234320-01-01 Flight Data Interface Management Unit (Fig. 32) collects and saves flight information for aircraft monitoring purposes. As a result of the accident, the unit was dislodged from its normal position and was found in the avionics compartment. On initial inspection, it was noticed that the unit had suffered significant mechanical damage. The PCMCIA quick-access memory card (Fig. 33) was located. An exterior inspection of the memory card revealed that the number “03” had been written by hand on its upper label (Fig. 33a), while the opposite side had a label with the number 2453-51M (Fig. 33б). The card

housing was deformed (Fig. 33в). Because of the deformation of the housing, a decision was made to open the unit and examine the printed circuit board. After opening the housing and extracting the circuit board, no damage to the exterior mounting elements was found (Fig. 34). The information from the PCMCIA memory card, consisting of DAR/SAT, SAR, and QAR/DAT files, was recorded normally.

*Figure 32. Teledyne Flight Data Interface Management Unit*

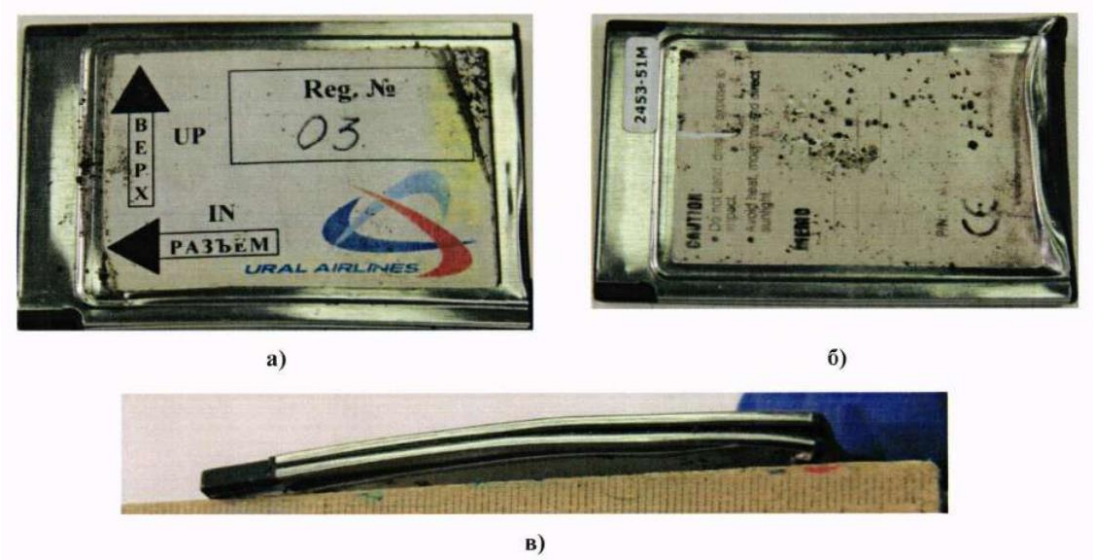



*Figure 33. Photograph of the RCMCIA memory card: а) top view; б) bottom view; в) deformation of the housing*

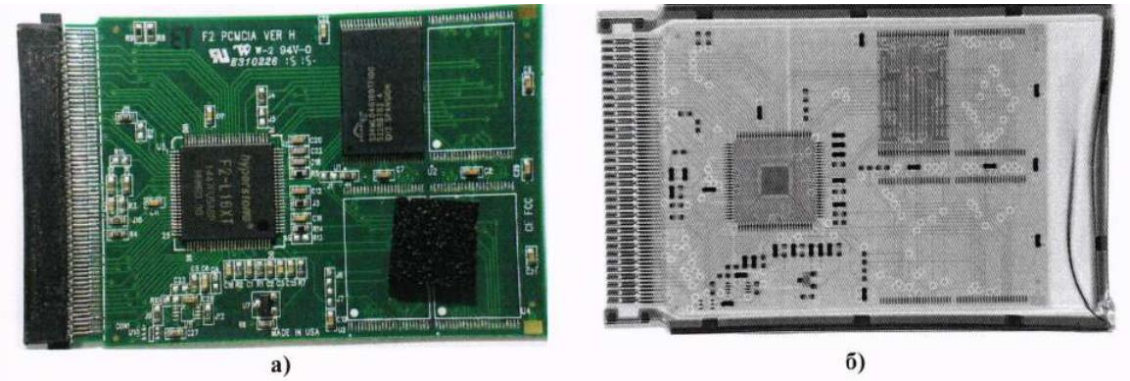



*Figure 34. Photograph of the printed circuit board of the RCMCIA memory card: а) printed circuit board; б) X-ray image of the memory card*

The flight recorders were decoded in a MAK laboratory.

Data from the accident flight were recorded. The quality of the recordings was good.

The FDR ceased recording at 03:15:17.9, the CVR at 03:15:18.9, and the DAR[11] at 03:15:13.3, and the QAR[12] at 03:15:17.9.

According to the manufacturer's explanation, on account of the significant airframe damage, the probable reason for the cessation of the recordings was damage to the electrical harnesses during the accident. Besides the connections to the recorders themselves, there could also have been damage to the data buses, which facilitate the transmission of data to the recorders.

Using the data from the recorders, graphs were created of various parameters during the accident flight (Fig. 35-39). The vertical red line represents the probable moment of the collision with the flock of birds. The determination of the moment of the bird strike was made on the basis of sounds recorded on the CVR and changes to engine parameters, beginning with the left engine. The margin of error in this determination was not more than 0.5 seconds.

[11] Digital ACMS Recorder
[12] Quick Access Recorder

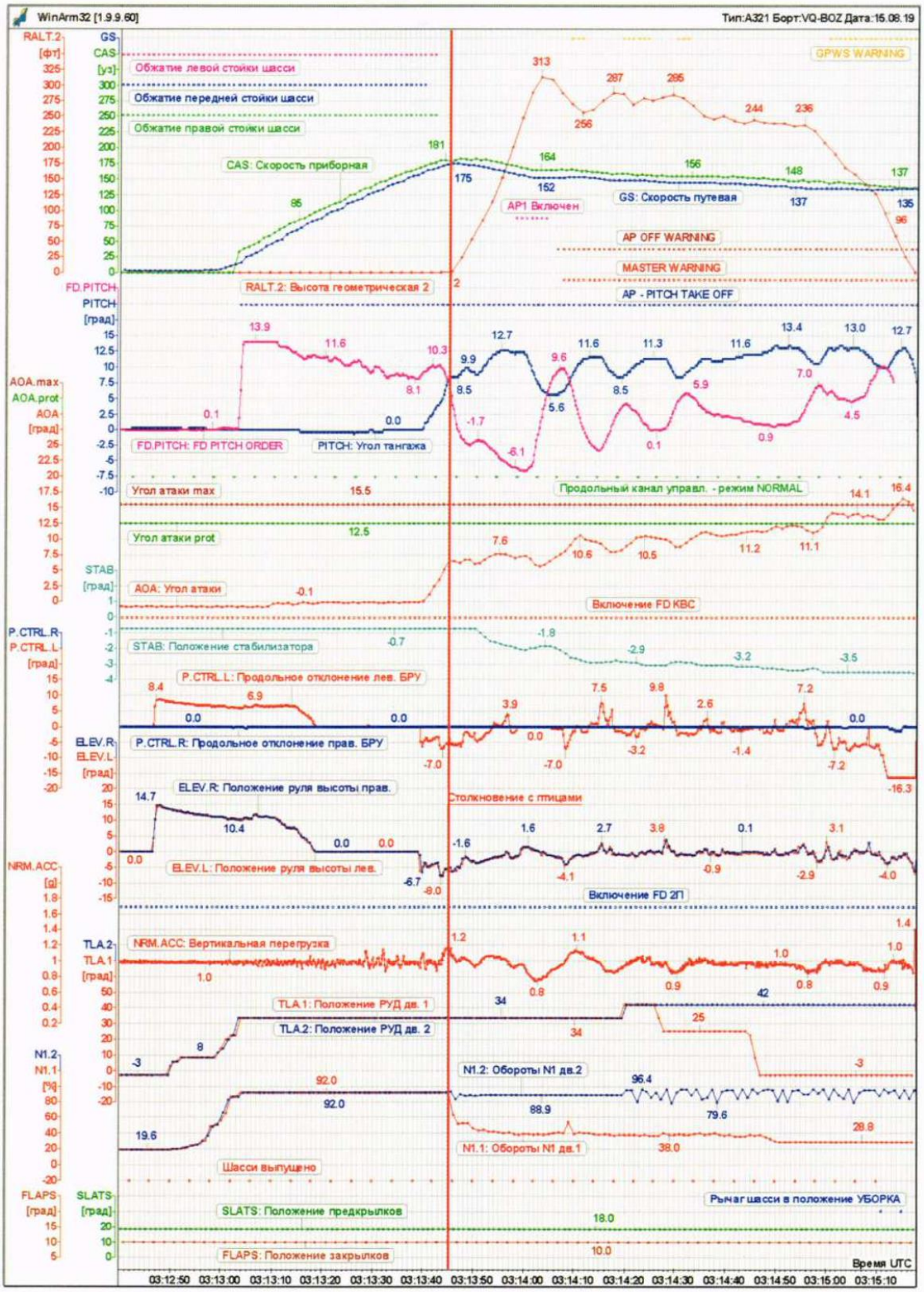



*Figure 35. Aircraft takeoff parameters (longitudinal channel)*

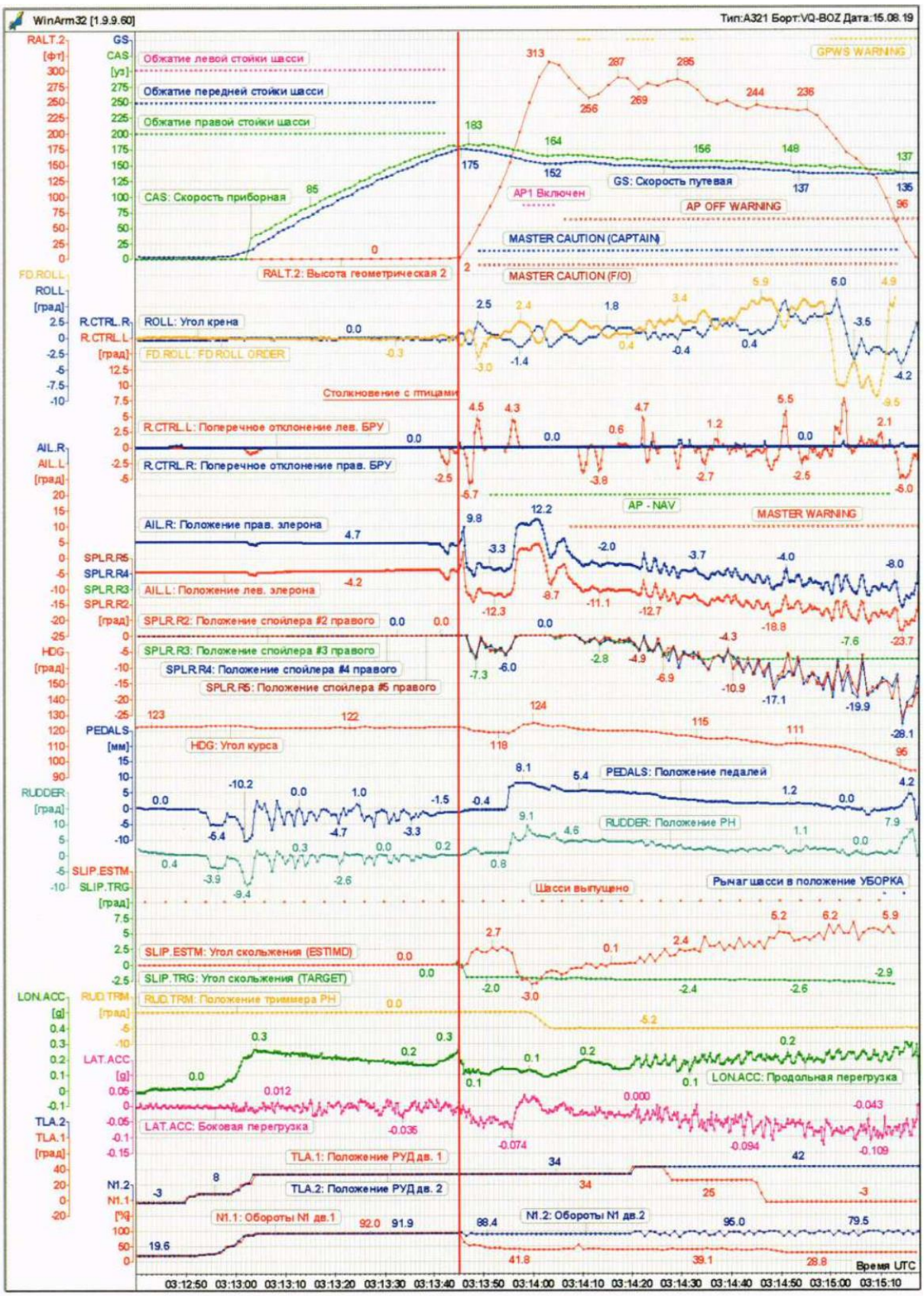



*Figure 36. Aircraft takeoff parameters (lateral channel)*

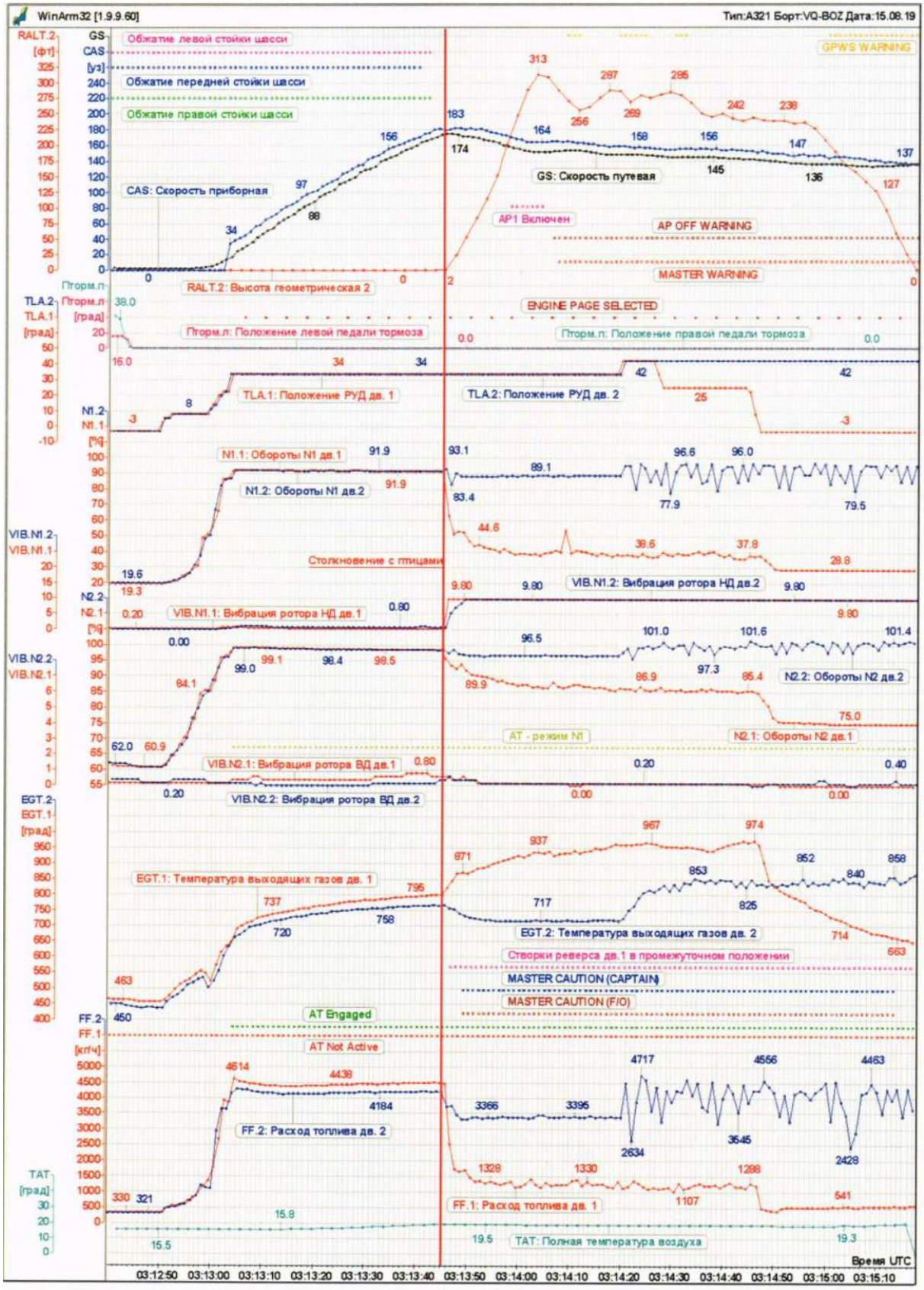



*Figure 37. Aircraft takeoff parameters (engine)*

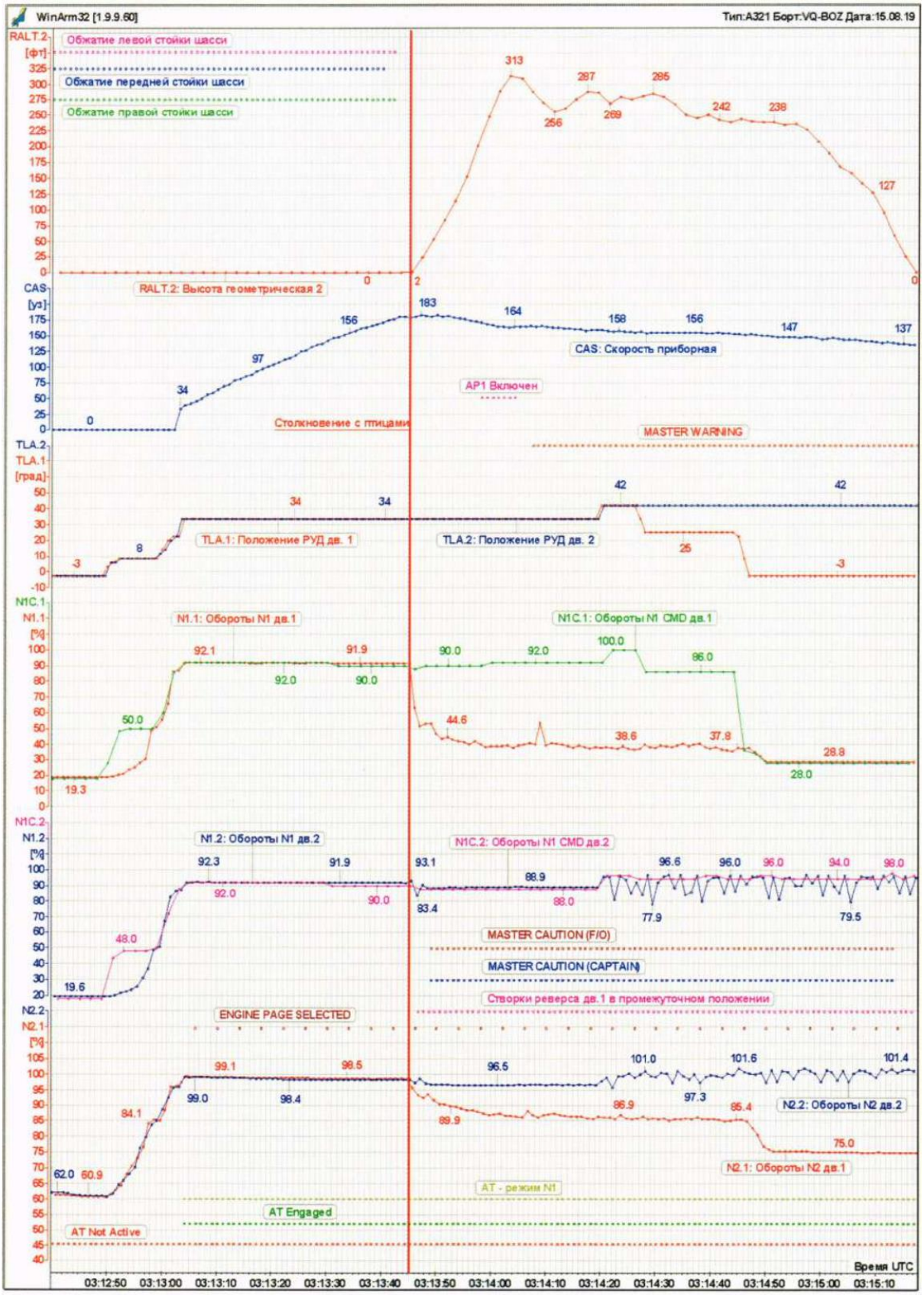



*Figure 38. Aircraft takeoff parameters (engine)*

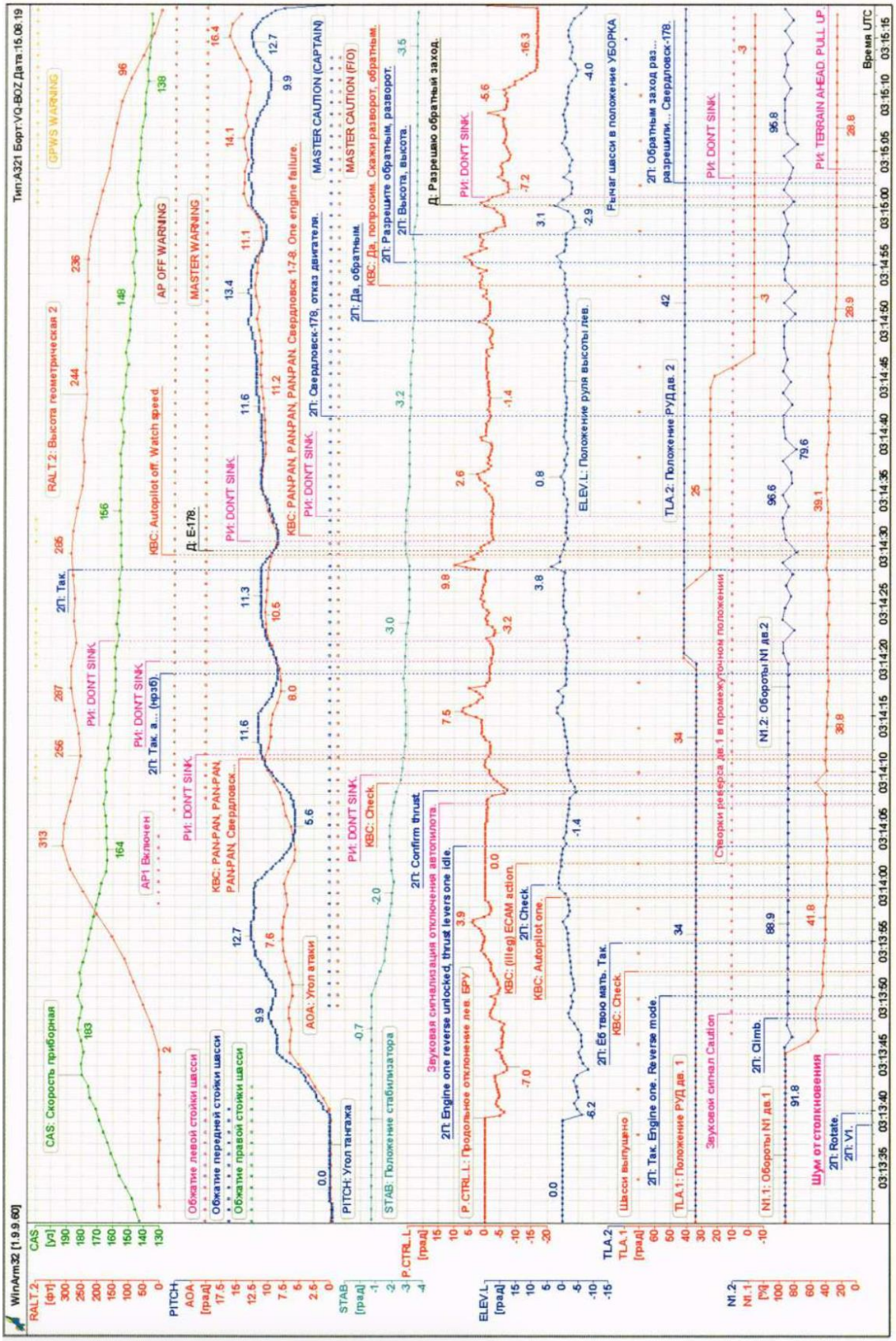



*Figure 39. Aircraft takeoff parameters with crew conversations*

### 1.12. Wreckage and Impact Information

An inspection of all 4,600 meters of Runway 12/30 at Ramenskoe Airport did not identify any aircraft debris. However, fragments of birds were found near the left side of the runway at a distance of 2 km from the departure end of Runway 12 (Fig. 40).

*Figure 40. Distribution of bird fragments found at Ramenskoe Airport*

The aircraft first contacted the ground with its right engine nacelle (Fig. 41) at a distance of ≈4,950 m from the departure end of Runway 12 and ≈680 m left of the runway extended centerline, at a point with coordinates 55˚30’42.40” N, 038˚14’50.60” E. Traces of ground contact by the lower fuselage were found a further ≈32 m along the aircraft’s direction of movement, and traces of contact by the left engine nacelle were found beyond this (Fig. 42).

***Note:*** *According to Appendix No. 77 of the Appendices to the Flight Planning Instructions for Ramenskoe Airport, entitled “Flight Planning for Civilian Flights,” the accident site is designated as a suitable area for forced landings. It is unlikely that the crew was aware of this information.*

*Figure 41. Location of the accident site relative to the departure end of Runway 12*

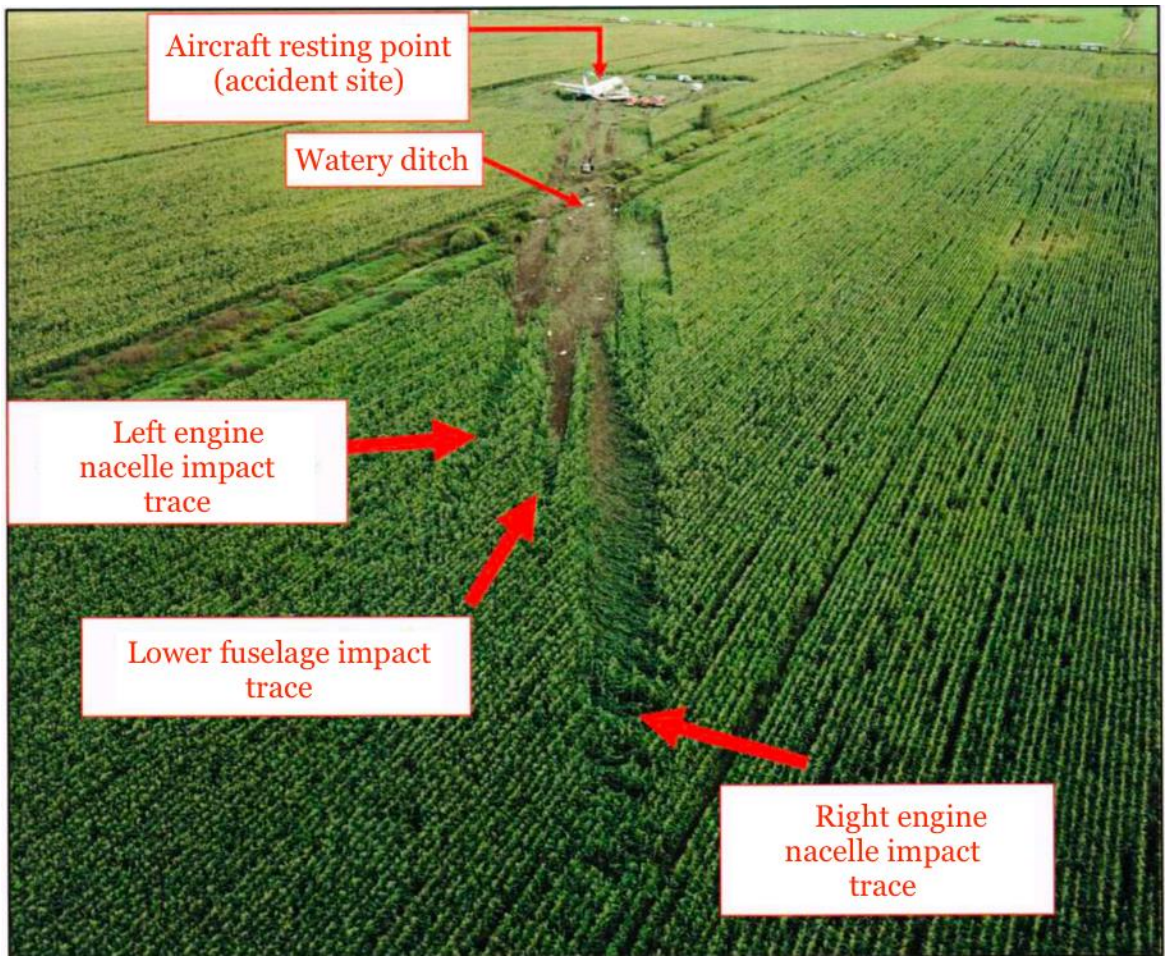



*Figure 42. Overview of the accident site*

The accident site was located in a flat field planted with corn rising to a height of 3 m. The elevation of the accident site is 105 m above sea level.

The nature of the impact marks showed that the aircraft traveled along a course of ≈104˚ true immediately after touchdown, with a slight right bank and nose up pitch angle.

In the right engine nacelle impact area, the stalks of corn were pressed to the ground not in the direction of the aircraft's motion, but in the opposite direction (Fig. 43), due to the jet blast. This showed that the right engine was producing appreciable power at impact.

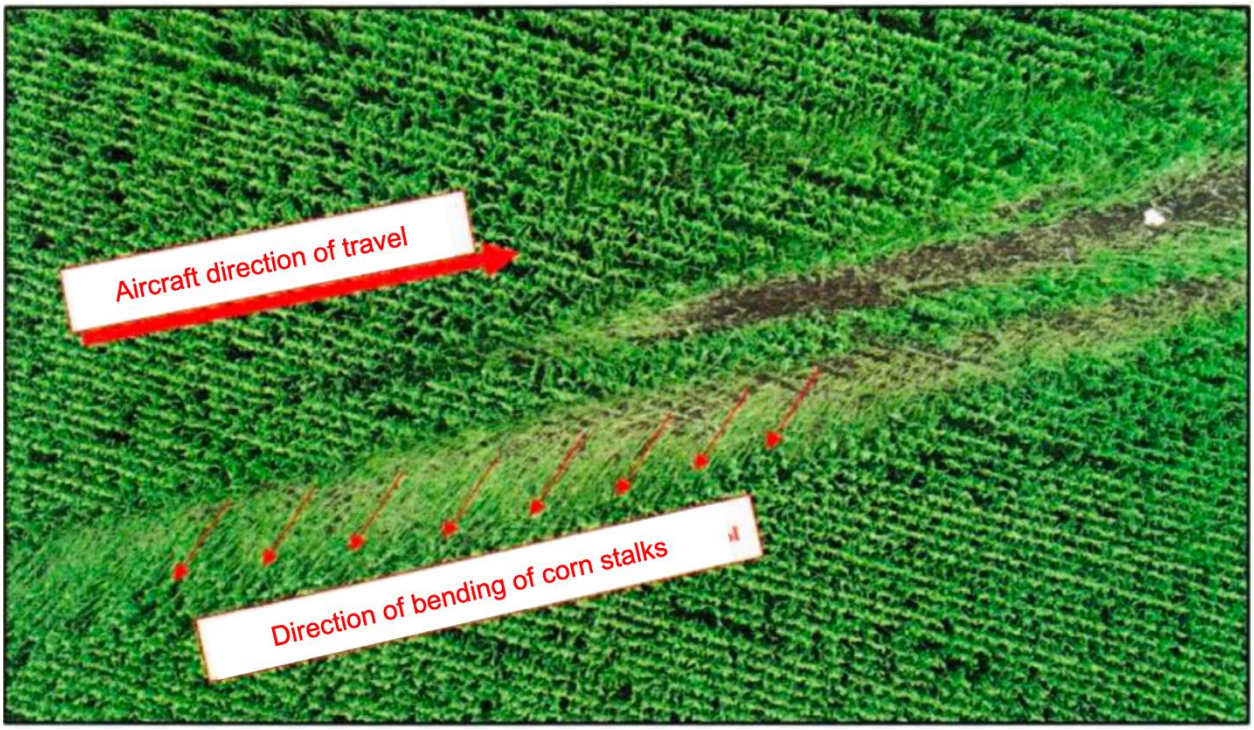



*Figure 43. Top view of the site of the first aircraft impact. The arrows indicate the direction of travel of the aircraft and the direction of bending of the corn stalks*

After this, the aircraft continued to slide across the ground on its lower fuselage and engine nacelles, as evidenced by the three corresponding traces along the entire ground movement trail.

A watery ditch was located along the ground movement trail at a distance of ≈160 m past the first point of impact (Fig. 44). At the point where the aircraft crossed it, the width of the ditch was 5-7 m and its depth was ≈1.5 m. The near side of the ditch (relative to the aircraft's direction of travel) was ≈0.5 m higher than the opposite side.

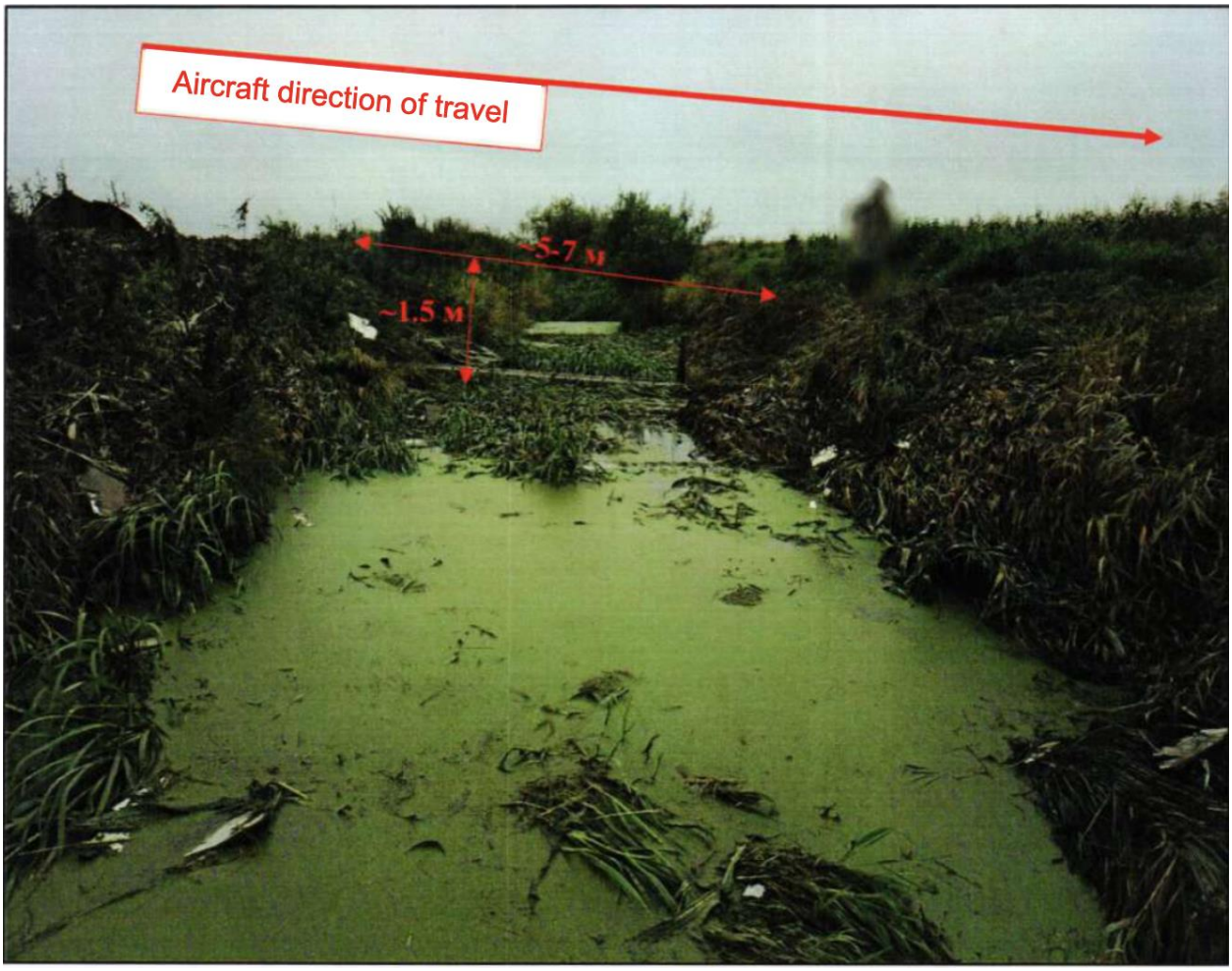



*Figure 44. Watery ditch*

After crossing the watery ditch, the aircraft continued for a further ≈190 m, then stopped at a point with coordinates 55˚30’39.00” N, 038˚15’09.34” E. This point was located ≈5,300 m from the end of the paved runway surface, and ≈815 m left of the extended runway centerline. Immediately after stopping, the aircraft rotated onto a heading of ≈126˚ true. There was no fire, neither on the ground nor in the air. Numerous aircraft fragments were found throughout the ground run; the larger fragments are listed in Table 1. A diagram of the accident site can be found in Fig. 45.

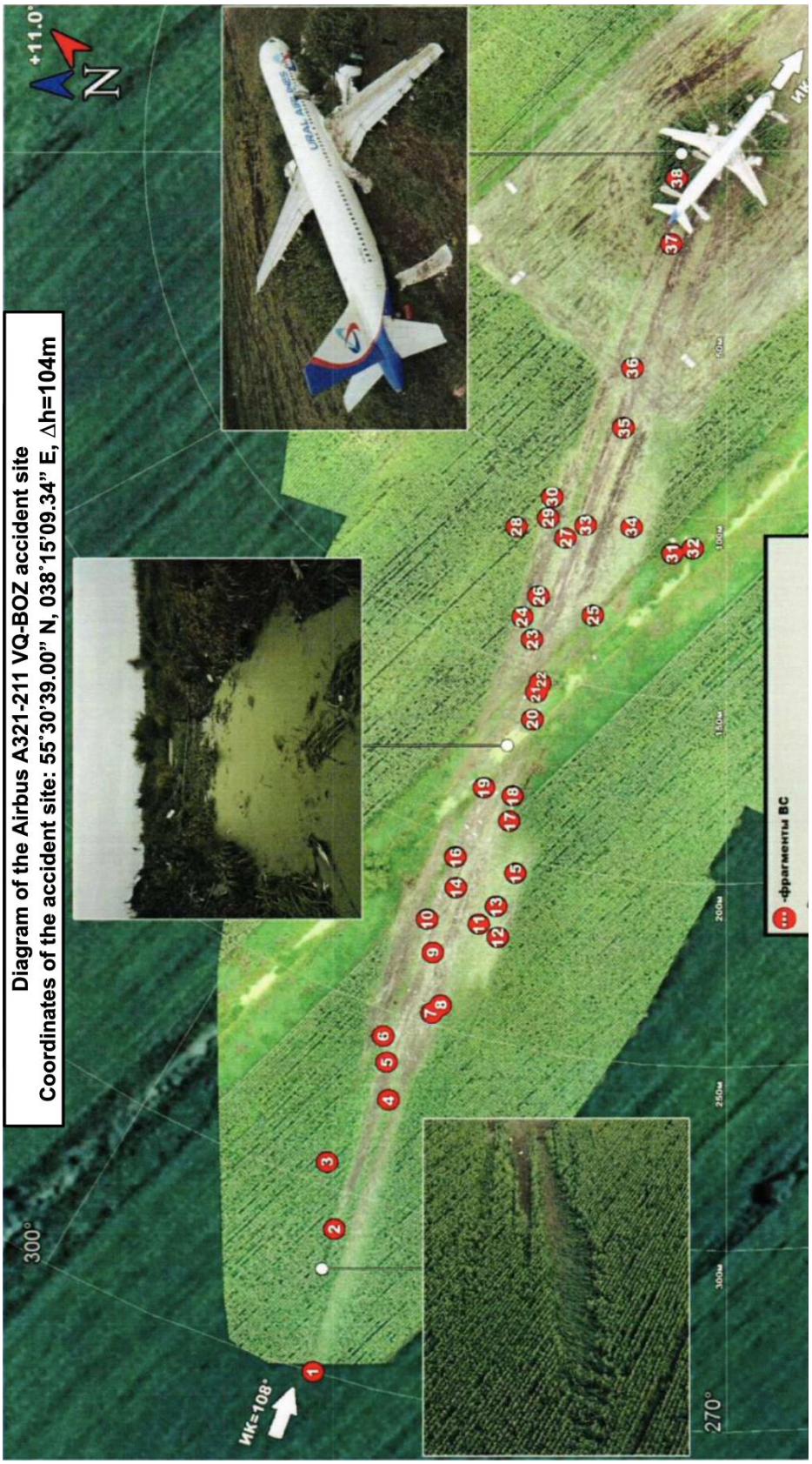
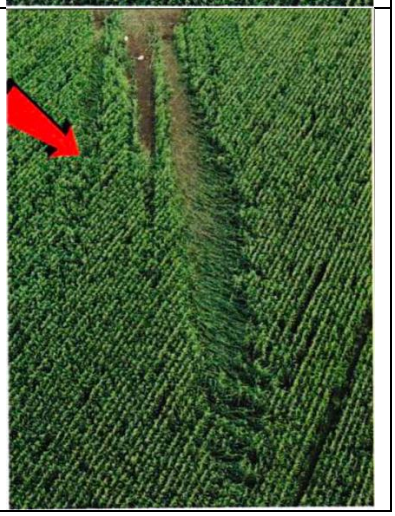
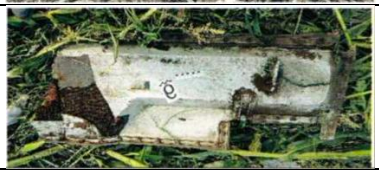



*Figure 45. Diagram of the accident site*

**List of aircraft fragments at the accident site**

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 01 | Location of first ground contact by the right engine | 55˚30’42.40” N, 038˚14’50.60” E | 0˚ | 0 m | |
| 02 | Location of lower fuselage ground contact | 55˚30’42.30” N, 038˚14’52.40” E | 95.25˚ | 31.7 m | |
| 03 | Location of left engine ground contact | 55˚30’42.50” N, 038˚14’53.30” E | 86˚ | 47.45 m |  |

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 04 | Aft section of the center wing fairing | 55˚30’41.90” N, 038˚14’54.80” E | 102˚ | 75 m | |
| 05 | Main landing gear door actuating mechanism | 55˚30’42.00” N, 038˚14’55.40” E | 98˚ | 85 m | |
| 06 | Fragment of main landing gear door | 55˚30’42.00” N, 038˚14’55.70” E | 98˚ | 90 m | |
| 07 | Fragment of main landing gear door | 55˚30’41.50” N, 038˚14’56.10” E | 106˚ | 100.3 m | |
| 08 | Fragment of right engine cowling | 55˚30’41.50” N, 038˚14’56.10” E | 106˚ | 100.3 m | |
| 09 | Fragment of lower left engine cowling | 55˚30’41.60” N, 038˚14’57.20” E | 102˚ | 118.2 m | |
| 10 | Left nose gear door | 55˚30’41.60” N, 038˚14’57.60” E | 101.30˚ | 125.2 m |  |

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 11 | Fragment of flap retraction mechanism fairing | 55˚30’41.20” N, 038˚14’57.50” E | 107˚ | 126.4 m | |
| 12 | Fragment of aft portion of right engine pylon | 55˚30’41.10” N, 038˚14’57.40” E | 108.5˚ | 125.8 m | |
| 13 | Fragment of center wing fairing | 55˚30’41.10” N, 038˚14’57.60” E | 108˚ | 129.2 m | |
| 14 | Two fragments of nose gear door | 55˚30’41.30” N, 038˚14’58.00” E | 104.6˚ | 134 m | |
| 15 | Right thrust reverser door hydraulic cylinder | 55˚30’40.90” N, 038˚14’58.30” E | 109˚ | 142.8 m | |
| 16 | Part of left engine accessory gearbox with a fragment of the starter and the generator | 55˚30’41.30” N, 038˚14’58.60” E | 103.5˚ | 144.2 m | |
| 17 | Braking system hydraulic accumulator | 55˚30’40.90” N, 038˚14’59.10” E | 107.2˚ | 156 m | |
| 18 | Fragment of center wing fairing | 55˚30’40.90” N, 038˚14’59.50” E | 106.5˚ | 162.7 m | |

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 19 | Fragment of main landing gear door | 55˚30’41.10” N, 038˚14’59.70” E | 104˚ | 164.5 m | |
| 20 | Fragment of engine cowling | 55˚30’40.80” N, 038˚15’00.50” E | 105.9˚ | 180.4 m | |
| 21 | Fragment of center wing fairing | 55˚30’40.60” N, 038˚15’01.20” E | 106.6˚ | 194 m | [Translator’s note: No photograph was provided.] |
| 22 | Left engine oil tank | 55˚30’40.60” N, 038˚15’01.20” E | 106.6˚ | 194 m | |
| 23 | Two fragments of hydraulic system filling panels | 55˚30’40.70” N, 038˚15’02.00” E | 104.7˚ | 206.6 m | |
| 24 | Fragment of left engine accessory gearbox with fuel manifold | 55˚30’40.80” N, 038˚15’02.30” E | 103.5˚ | 211 m | |

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 25 | Fragment of center wing fairing | 55˚30’40.20” N, 038˚15’02.20” E | 108.5˚ | 214.4 m | |
| 26 | Two fragments of left engine fan blades | 55˚30’40.70” N, 038˚15’02.70” E | 104˚ | 218.5 m | |
| 27 | Fragment of the upper part of the left engine with part of the center section and hydraulic fluid tank | 55˚30’40.40” N, 038˚15’03.60” E | 105.2˚ | 236.2 m | |
| 28 | Fragment of the RAT (Ram Air Turbine) | 55˚30’40.75” N, 038˚15’03.83” E | 102.2˚ | 237.8 m | |
| 29 | Fragments of left engine cowling | 55˚30’40.60” N, 038˚15’04.10” E | 103.2˚ | 243.2 m | |

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 30 | Fragment of left engine cowling | 55˚30’40.60” N, 038˚15’04.10” E | 103.2˚ | 244.2 m | |
| 31 | Fragment of right engine cowling | 55˚30’39.49” N, 038˚15’03.44” E | 111.9˚ | 242.4 m | |
| 32 | Fragment of right winglet | 55˚30’39.33” N, 038˚15’03.44” E | 113˚ | 244 m | |
| 33 | Hydraulic accumulator | 55˚30’40.30” N, 038˚15’03.70” E | 105.8˚ | 238.8 m | |
| 34 | Fragment of right engine air intake pipeline | 55˚30’40.30” N, 038˚15’03.70” E | 108.5˚ | 244 m | |
| 35 | Electric hydraulic pump | 55˚30’40.00” N, 038˚15’05.20” E | 106.2˚ | 266.6 m | |

| No. | Fragment | Coordinates | Azimuth from point 01 | Distance from point 01 | Photograph |
|---|---|---|---|---|---|
| 36 | Fragment of left engine cowling | 55˚30’39.90” N, 038˚15’06.30” E | 105.7˚ | 286 m | |
| 37 | Engine ignition unit | 55˚30’39.52” N, 038˚15’08.20” E | 106.1˚ | 321.2 m | |
| 38 | Fragment of left engine nacelle with reverser door | 55˚30’39.40” N, 038˚15’08.90” E | 106.1˚ | 334.1 m | |
| 39 | End of aircraft ground track (accident site) | 55˚30’39.00” N, 038˚15’09.34” E | 107.8˚ | 350 m | |

### 1.13. Medical and Pathological Information

After the accident, the First Officer was taken to the Zhukovskiy City Clinical Hospital. After being examined, he was diagnosed with “a level 1 compressional fracture of vertebra Th12 and an edge fracture of the sternum.”

Following blood and urine tests of the Captain and the First Officer by court medicine experts, “no traces of alcohol, drugs of abuse, medical substances with psychological effects, or metabolites thereof, were found.”

In all, 78 passengers, including 19 children, received medical attention. Thirty-two patients, including 10 children, were taken to hospitals by paramedics. Thirty patients, including the 10 children, were treated and released; two adults were hospitalized.

The remainder were given medical treatment by paramedics at Zhukovskiy Airport.

### 1.14. Survival Factors

During the flight, all flight and cabin crew members were sitting in their assigned seats and were restrained by seat belts. The passengers were seated throughout the passenger cabin and were restrained by seat belts (Fig. 46).

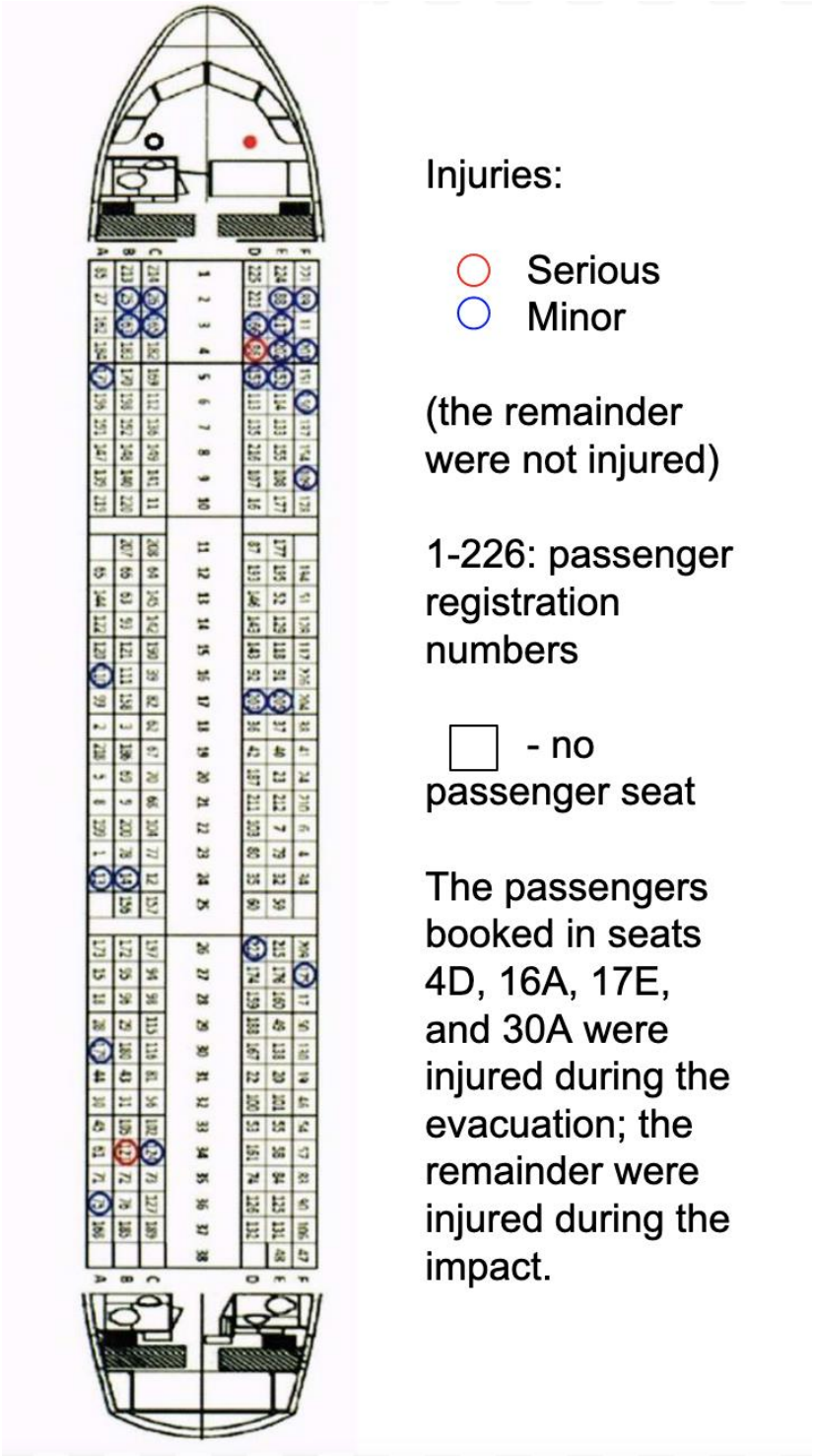



*Figure 46. Passenger seating diagram*

According to the First Officer, he was injured because he braced himself with one hand against the top of the instrument panel during the impact.

***Note:*** *The following is an excerpt from the interview with the First Officer:*

*Q: "What caused your injuries?"*
*A: "Possibly the fact that I had one hand braced against the visor, I don't remember whether it was the left or right."*
*Q: "Could the serving tray have come down during the landing? Could it have struck you?"*
*A: "The serving tray had been removed from the cockpit. It couldn't have struck me."*

In the opinion of an expert, "Injuries similar to those sustained by the First Officer (considering the lack of injuries to the Captain, who was sitting near him in the cockpit, as well as passengers seated in the cabin) could only have occurred if he did not assume the brace position for touchdown and ground rollout during the emergency landing."

After being examined by medical experts, 25 passengers were classified as having sustained minor injuries, and two passengers were classified as having sustained moderate injuries. Twenty-three passengers received injuries during impact, and 4 passengers (booked in seats 4D, 16A, 17E, and 30A) received injuries during the evacuation while using the emergency escape slides at the accident site.

No peculiarities of the aircraft design were identified which may have affected the seriousness of the injuries.

### 1.15. Rescue Team Actions

After receiving the crew's report of an engine failure and request to return to the reciprocal runway, the tower supervisor[13] activated the emergency alert at 03:15.

***Note:*** *The instructions for organization and accomplishment of search and rescue activities at the airport and within Ramenskoe Airport's area of responsibility state the following:*

*"Notification and issuance of alarms*
*…*
*An emergency alert is issued when an accident occurs suddenly, or when an aircraft in trouble is expected to land at Ramenskoe Airport within the next 30 minutes.*
*…*
*Notification of conduct of search and rescue operations*
*The search and rescue team shall deploy if the accident site is not known. Upon receiving an emergency alert, the crew of the helicopter and the medical response*

[13] Translator's Note: The phrase used in the original is "руководитель полетов" which literally means "manager of flights." From context I believe this is a supervisory air traffic controller, but I'm not certain.

*team shall arrive at the location of the helicopter on standby (the ground search and rescue team deployment point). Upon receiving the emergency alert, the airborne rescue group shall arrive at the helicopter boarding point at the intersection of runways 4 and 1, and the senior airborne rescue group member shall announce by radio to the commander of the helicopter that the group is ready to board the helicopter. After the helicopter has taxied out, the airborne rescue group shall board the helicopter upon receiving permission from the commander.*

*…*

*Takeoff of the helicopter and departure of the ground search and rescue team should occur no later than 30 minutes after receipt of the emergency alert in summer and 45 minutes in winter.*

*…*

*—[I]f the accident occurred near the airport or within Ramenskoe's Airport's 10-kilometer area of responsibility, then the medical response team and the airborne rescue group shall fly to the site in the helicopter, and the ground search and rescue team shall drive to the site of the accident in their own transportation;*

*…*

*—[I]f the helicopter cannot take off, then the medical response team and ground search and rescue team shall drive to the site of the accident in their own transport."*

At 03:22, the M. M. Gromov Flight Institute Aircraft Search and Rescue Team received the signal to assemble, and at 3:23 they were informed of the approximate location of the aircraft. Notification of the accident (landing of the aircraft beyond the runway) was immediately received from the crew at 03:16. From this time, the crew continued to maintain radio contact with the controller.

At 03:25, four members the ground search and rescue team and a paramedic deployed to the accident site in a KAMAZ 43114 automobile, which arrived at the accident site at 03:40. The senior member of the ground search and rescue team reported the exact position of the aircraft and that the accident site was being cordoned off.

The helicopter with the airborne rescue services was not deployed.

At 03:42, a Ramport Aero transportation organization team was deployed to the accident site, consisting of 15 staff and four buses. Fifteen members of the Zhukovskiy Airport Police travelled with them, as well as two automobiles and four members of the Ramport Aero Aviation Safety Service, who collectively arrived at the accident site at 04:25.

At 04:50, the passengers were evacuated from the accident site, and the injured were taken to Ramenskoe Central Municipal Hospital and Zhukovskiy City Clinical Hospital.

At 03:20, a witness reported the accident to the Russian Ministry of Emergency Situations Moscow Oblast' Crisis Management Center. The following assets were sent to the accident site:

- A fire rescue team from station 42 of the 26th Moscow Oblast' Federal Firefighting Brigade, which arrived at the accident site at 03:30.
- Specialists from the Ramspas Rescue Team arrived at the accident site at 03:30.

- A fire rescue team from station 127 of the 26th Moscow Oblast' Federal Firefighting Brigade, which arrived at the accident site at 03:40.
- A fire rescue team from supporting station 343 of the Ramenskoe Territorial Forces and Means Agency of the Moscow Oblast' Fire Rescue Service, which arrived at the accident site at 3:54.
- Two fire rescue teams from station 343 of the Ramenskoe Territorial Forces and Means Agency of the Moscow Oblast' Fire Rescue Service, which arrived at the accident site at 4:01 and 4:02.
- Two fire rescue teams from station 262 of the Ramenskoe Territorial Forces and Means Agency of the Moscow Oblast' Fire Rescue Service, which arrived at the accident site at 3:54.
- Two fire rescue teams from station 340 of the Ramenskoe Territorial Forces and Means Agency of the Moscow Oblast' Fire Rescue Service, which arrived at the accident site at 4:07 and 4:13.
- A fire rescue team from supporting station 343 of the Ramenskoe Territorial Forces and Means Agency of the Moscow Oblast' Fire Rescue Service, which arrived at the accident site at 4:13.

At 03:23, 10 ambulance brigades from the Ramenskoe City District were dispatched to the accident site and arrived at 03:39.

At 03:30, the following assets were dispatched to the accident site:

- An operating group from the Russian Ministry of Emergency Situations Moscow Oblast' Crisis Management Center, which arrived at the accident site at 04:55.
- An operating group from the Ramenskoe Fire Rescue Garrison, which arrived at the accident site at 03:55.
- A fire rescue team from Special Fire Rescue Station 45 of the Special Administration No. 3 of the Federal Firefighting Service, which arrived at the accident site at 04:12.
- A fire rescue team from Special Fire Rescue Station 44 of the Special Administration No. 3 of the Federal Firefighting Service, which arrived at the accident site at 04:20.

There was no fire at the accident site. Firefighting personnel sprayed foam on the aircraft's engines and wings in order to avoid any ignition.

The M. M. Gromov Flight Institute Aircraft Search and Rescue Team possesses a certificate, No. 15-211-002, allowing it to conduct rescue operations and other undefined tasks in emergency situations, issued by Rosaviatsiia on 10/05/2017 and valid until 10/05/2020. The rescue service of the M. M. Gromov Flight Institute Aircraft Search and Rescue Team acted in accordance with the Protocol for the Organization and Conduct of Search and Rescue Activities at the Airport and in the Ramenskoe Airport Area of Responsibility, which was approved by the general director of the M. M. Gromov Flight Institute on 31//01/2017.

The actions of the rescue teams did not affect the severity of the consequences of the accident.

### 1.15.1. Condition and Use of Aircraft Emergency Equipment

All of the aircraft's portable oxygen and emergency equipment was present and in its nominal position; none of this equipment was used during the evacuation.

All of the aircraft's emergency escape slides (four on the left side and four on the right) automatically activated when the doors were opened and deployed in the proper positions.

## 1.16. Tests and Research

### 1.16.1. Investigation of Fuel and Engine Oil

For the purposes of the investigation, fuel samples were taken from the interior of the aircraft's left fuel tank and from the depressurized right engine fuel supply lines, along with oil from the right engine oil tanks.

The fuel samples were sent to the Airport Activities and Aviation Fuel Research Center (RC-28) of the State Research Institute for Civil Aviation.

***Note:*** *1. From conclusion No. 170-2019/TsS GSM-AP:*

*"5.1. The sample, taken from the interior of the left wing tank (drain tap L-1), contained two non-mixing fluids.*

*According to the measured indicators of its chemical and operational quality, outward appearance, infrared spectra, and behavioral characteristics, the upper layer of the sample was identified as jet fuel, and the lower layer was identified as water.*

*The quality indications established for the fuel (upper layer) corresponded to the statistical data for fuel sampled from aircraft fuel systems during normal operating conditions.*

*The quality indications established for the water (lower layer) corresponded to the statistical data for water deposits drained from aircraft fuel systems during normal operating conditions.*

*5.2. The sample taken from the depressurized engine fuel supply line consisted of two non-mixing fluids.*

*According to the measured indicators of its chemical and operational quality, outward appearance, infrared spectra, and behavioral characteristics, the upper layer of the sample was identified as jet fuel, with an increased tar content and foreign admixture.*

*The lower layer was identified as a water solution containing foreign dissolved organic matter. The presence of foreign impurities in the fuel and water layers, and most likely the increased tar content in the fuel, were caused by the depressurization of the engine fuel supply lines and the introduction of chemical reagents used in fire extinguishers."*

*2. From conclusion No. 175-2019/TsS GSM-AP:*

*"5.1. According the measured indicators of its chemical and operational quality, the results of a luminescence analysis, infrared spectra, and a thin layer-*

*chromographic analysis, the oil taken from the oil tanks of engines 1 and 2 was identified as synthetic oil marketed as Mobil Jet Oil II.*
*5.2. According to the measured chemical indicators, outward appearance, luminescence characteristics, and infrared spectra, the oil taken from the No. 1 oil tank is similar to the oil taken from the oil tank in engine No. 2.*
*5.3. The chemical and operational qualities measured during testing of the oil were found to correspond to the nominal values for MIL-PRF-23699 type synthetic oil after being used in normal aircraft operations.*
*5.4. The concentration of mechanical impurities in the form of products of wear and tear and/or pollution during the oil tests did not exceed the normal values for similar brands of synthetic oil sampled from various aircraft types during normal operations.*

### 1.16.2. Investigation of Bird Fragments

The bird fragments found on the runway at Ramenskoe Airport and in the left wheel well of the aircraft, as well as feathers and biological matter found on the exterior of the aircraft, were sent for analysis at the A. N. Severtsov National Research Institute for Ecology and Evolution.[14]

The following section describes the findings and conclusions of the ornithological and DNA analyses carried out on the bird carcasses by experts of the Russian Academy of Sciences' A. N. Severtsov Institute for Ecology and Evolution.

1. Bird carcasses, fragments of feathers and muscle tissue, and samples of biological matter scraped from the exterior of the aircraft, the runway at Ramenskoe Airport, and the accident site, were submitted for analysis.

2. By comparing the samples' measured nucleotide sequences with homologous sequences from GenBank, with help from the BLAST program, the samples were found to be a 100% match with homologous DNA fragments from gulls of the genus Larus. More specifically, the full identity of the sample DNA fragment was established using the homologous sequences of the European herring gull (*Larus argentatus*) and related species from this group, namely *Larus fuscus, Larus dominicanus, Larus heuglini,* and *Larus occidentalis,* whose ranges have not yet been fully established.

3. A comparison was carried out between the linear microstructures from the sample feather material and elements of collected microstructures from various types of gulls. A match was found between six of the measurements from the sample feather fragments and representative feathers from large white-headed gulls collected in the Russian Academy of Sciences database. Considering the feathers' macrostructural (color, size, feather configuration) and microstructural (pigmentation, form and number of contours and down shafts) indicators, the collision could have involved European herring gulls (*Larus argentatus*), Caspian gulls (*Larus cachinnans*), Heuglin's gulls (*Larus heuglini*), or lesser black-backed gulls (*Larus fuscus*). The European herring gull and Caspian gull nest in Moscow Oblast' and several neighboring oblasts.

The Heuglin's gull and lesser black-backed gull nest in the northern and northwestern parts of European Russia and are sometimes encountered in the Moscow area during the spring and fall migrations.

[14] A DNA analysis of the bird fragments found inside the engines during their teardown was conducted in France. The results related to the birds' species generally concur.

4. A comparative analysis was made between the subject specimens and the carcasses and carcass fragments of large white-headed gulls and other types of gulls preserved in the collections of the MGU Zoological Research Museum and the Russian Academy of Sciences. This analysis established that the coloration of the carcasses and carcass fragments of adult gulls involved in the accident did not match with the coloration of lesser black-backed gulls or Heuglin's gulls. Furthermore, the accident took place too early for the migration of Heuglin's and lesser black-backed fledglings. Both of these types also migrate alone, so it is very unlikely that the aircraft struck a flock of fledglings belonging to either of these species. Most probably, the collision involved a flock of European herring gulls or Caspian gulls consisting of either 13 or 15 individuals. European herring gulls and Caspian gulls are closely related and both nest in Moscow oblast'. Distinguishing between the two would be difficult because their calls are the main differentiating feature. The situation is further complicated by the fact that European herring gulls and Caspian gulls frequently interbreed in the central part of European Russia, and hybrid individuals currently comprise a significant percentage of the nesting groups in the Moscow area.

The flock consisted of individuals of various ages, including birds born earlier that year (fledglings), sexually mature birds over three years old, and immature individuals with ages between one and three years.

5. Based on the genetic analysis and feather structure, the collision involved large white-headed gulls of the Gull (Laridae) family of the Seabird (Charadriiformes) order.

Male European herring gulls weigh between 909 and 1,496 g (2-3.3 lbs), while females weigh between 946 and 1,385 g (2.1-3.05 lbs). Their wingspan ranges from 120 to 157 cm, their wings are between 39.5 and 47.2 cm long, their shank bones are between 61 and 73 mm long, and the length of their beaks ranges from 48 to 61 mm.

Male Caspian gulls weigh between 750 and 1,193 g (1.65-2.63 lbs), while females weigh between 680 and 1,037 g (1.5-2.28 lbs). Their wingspan ranges from 136 to 160 cm, their wings are between 39.5 and 46.2 cm long, their shank bones are between 62 and 76 mm long, and the length of their beaks ranges from 50 to 66 mm.

The speed of a flock of large gulls can vary from 40 to 60 km/h.

Nesting season for European herring gulls and Caspian gulls in the Moscow area lasts from mid-April to mid-to-late July, during which time the birds are attached to a particular colony, although they may venture several kilometers (sometimes several dozen kilometers) away from the colony.

At the conclusion of the nesting season, the birds abandon their nesting colonies, and the adults and fledglings begin to wander aimlessly. During this period, gulls can be very dangerous to aircraft, because they tend to concentrate in their preferred rest spots, which are normally level, open spaces devoid of plants. At first, the birds will choose spots close to the colony, but later, they may accumulate in areas several kilometers from their nesting sites. During this period the gulls may be attracted by airport runways. The appearance of such flocks is unpredictable outside the immediate vicinity of their colonies. Airport runways can also appear to gulls as attractive resting places during their daily flights between their feeding locations (household waste dumps) and the local reservoirs. How much the fledglings can fly is uncertain; it may be more difficult for them to avoid airplanes than for the adults.

6. Therefore, in generalizing the findings of the genetic analysis, feather form analysis, and biological analysis, the commission of experts concludes that the collision at Zhukovskiy

Airport involved fledglings, immature individuals older than one year, and adults, which were either European herring gulls or Caspian gulls.

### 1.16.3. Results of Engine Examination

A description of the condition of the engines immediately after the accident can be found in section 1.3 of this report.

An analysis of the thrust characteristics of the engines both before and after the bird strike can be found in section 1.16.4.2 of this report.

An analysis of the conformity of the engines' behavior to the certification requirements after the bird strike can be found in section 2.3.3 of this report.

This section contains the results of the engine examination conducted by order of the Commission at the manufacturer's headquarters in France. A complete dismantling and examination of the engines was conducted by representatives of the Commission and the BEA with the participation of specialists from Airbus and EASA.

**Engine No. 1 (left, ESN – 575728)**

Fig. 47 shows an exterior view of the fan stage under examination.

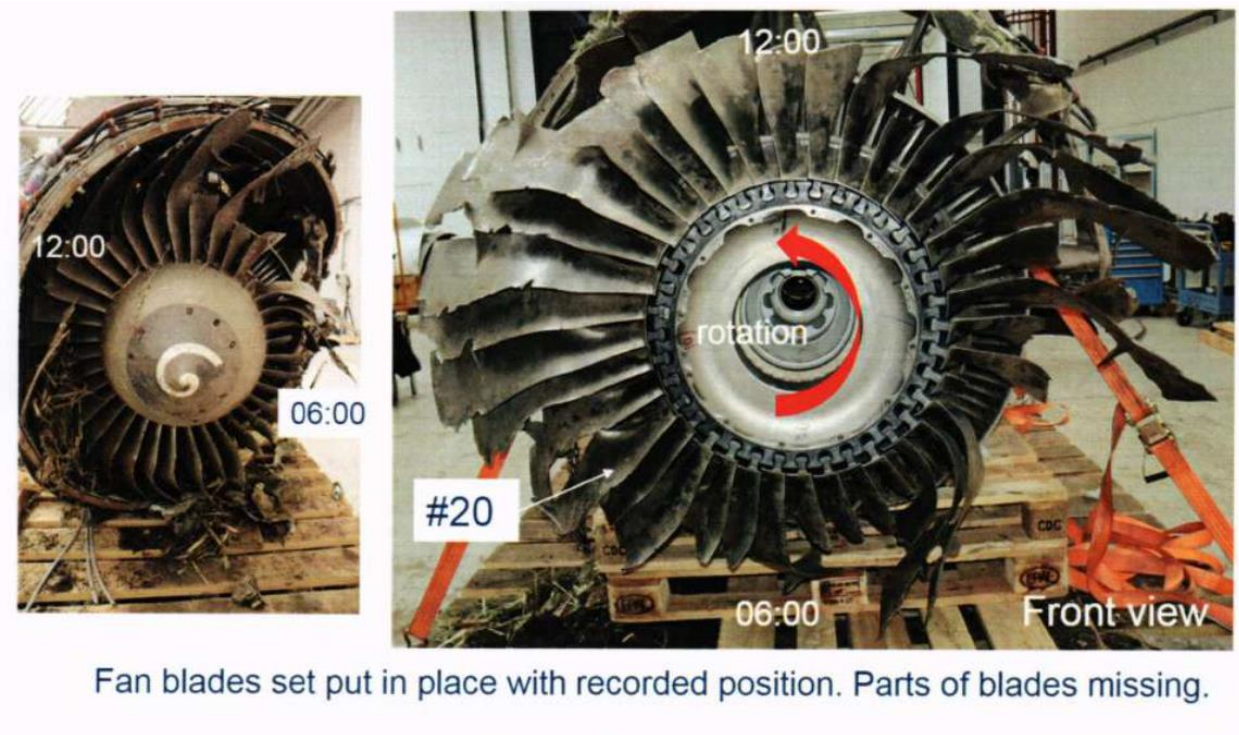



*Figure 47. Exterior view of the left engine fan stage under examination.*

Based on its experience conducting bird ingestion certification tests, the manufacturer explained that the most reliable indicator used to determine the location and energy of an impacting object (or bird) are rounded areas of damage, or bulges, on the forward edges of the fan blades. Fig. 48 shows an example assessment of the location and magnitude of damage to fan blade No. 9 from the left engine. At a point 20% above the blade root, a 4.5 mm bulge was

observed (the actual size of the observed bulge is 5 mm, of which ≤0.5 mm is part of the blade's nominal construction).

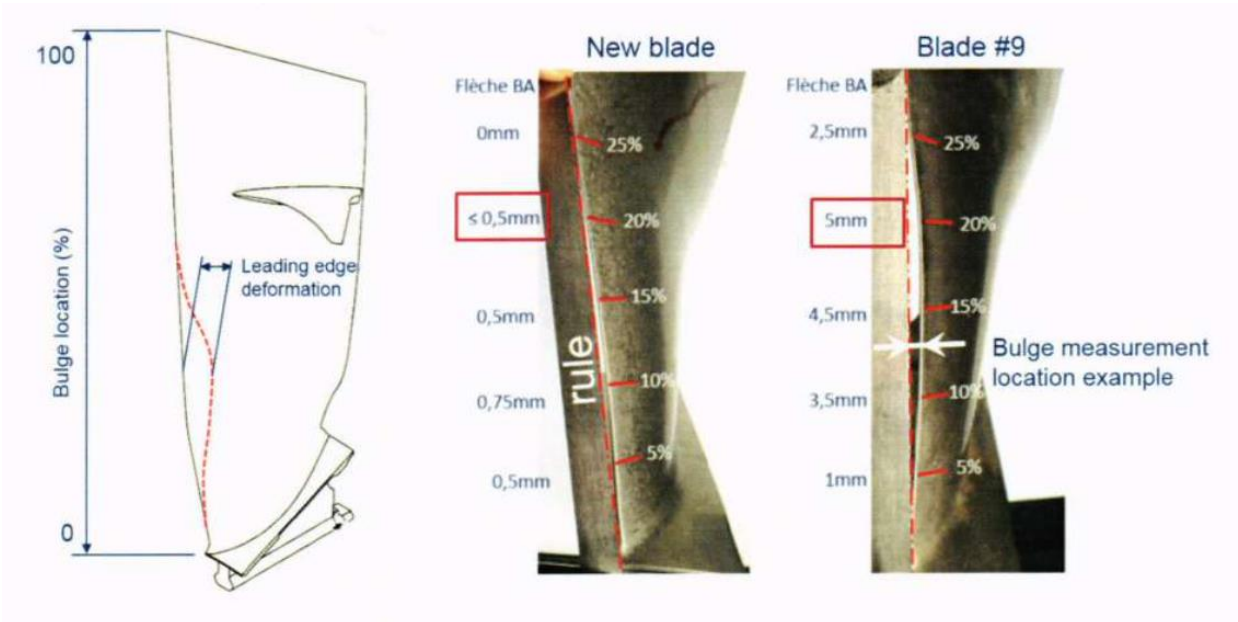
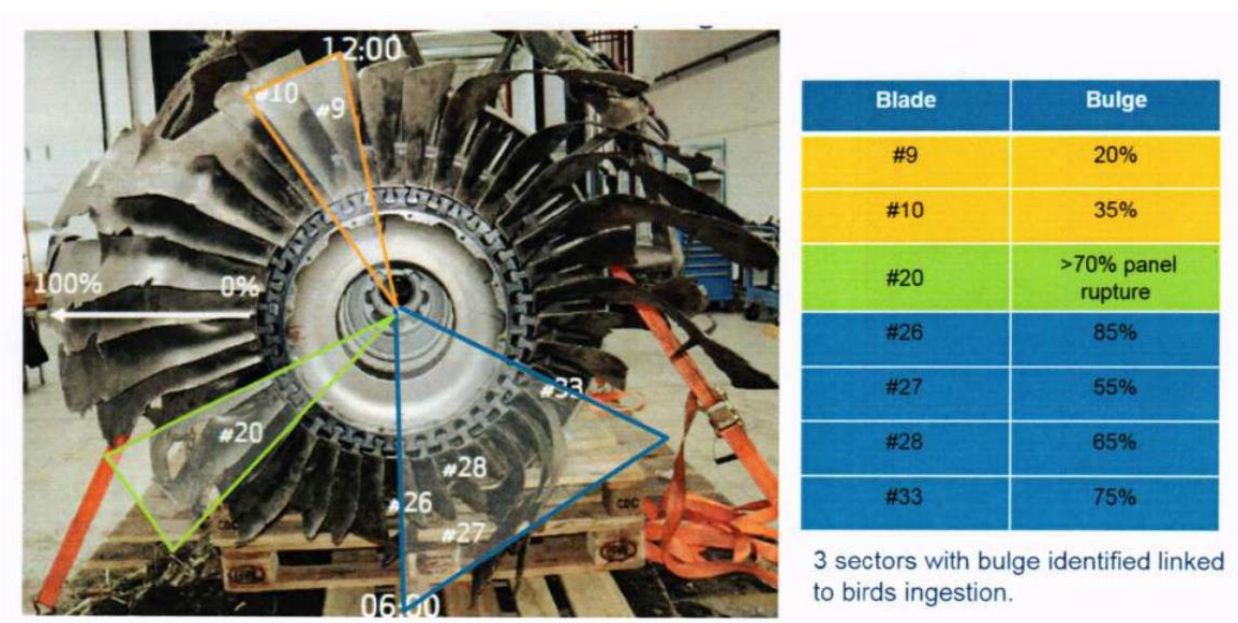



*Figure 48. Example assessment of the location and magnitude of a bulge*

Fig. 49 shows the locations of three zones, or sectors, of the fan stage that each suffered at least one bird impact. The table in the figure shows the locations and sizes of the observed deformations relative to the length of the blade. In cases where fan blades or parts of fan blades were missing, it was not possible to determine whether birds impacted these areas.




| Blade | Bulge |
|---|---|
| #9 | 20% |
| #10 | 35% |
| #20 | >70% panel rupture |
| #26 | 85% |
| #27 | 55% |
| #28 | 65% |
| #33 | 75% |

3 sectors with bulge identified linked to birds ingestion.

*Figure 49. Damage to left engine fan blades*

By comparing the size of the deformations with those observed during certification testing and during actual investigations, the manufacturer determined that the left engine ingested at least three birds, of which one (which impacted the yellow sector in Fig. 49) was categorized as "large;" that is, with a weight between 2.5 lbs (1.13 kg) and 4 lbs (1.81 kg). [15]

During the course of the investigation, a rupture was discovered in the upper panel of fan blade No. 20 on the left engine (Fig. 50).

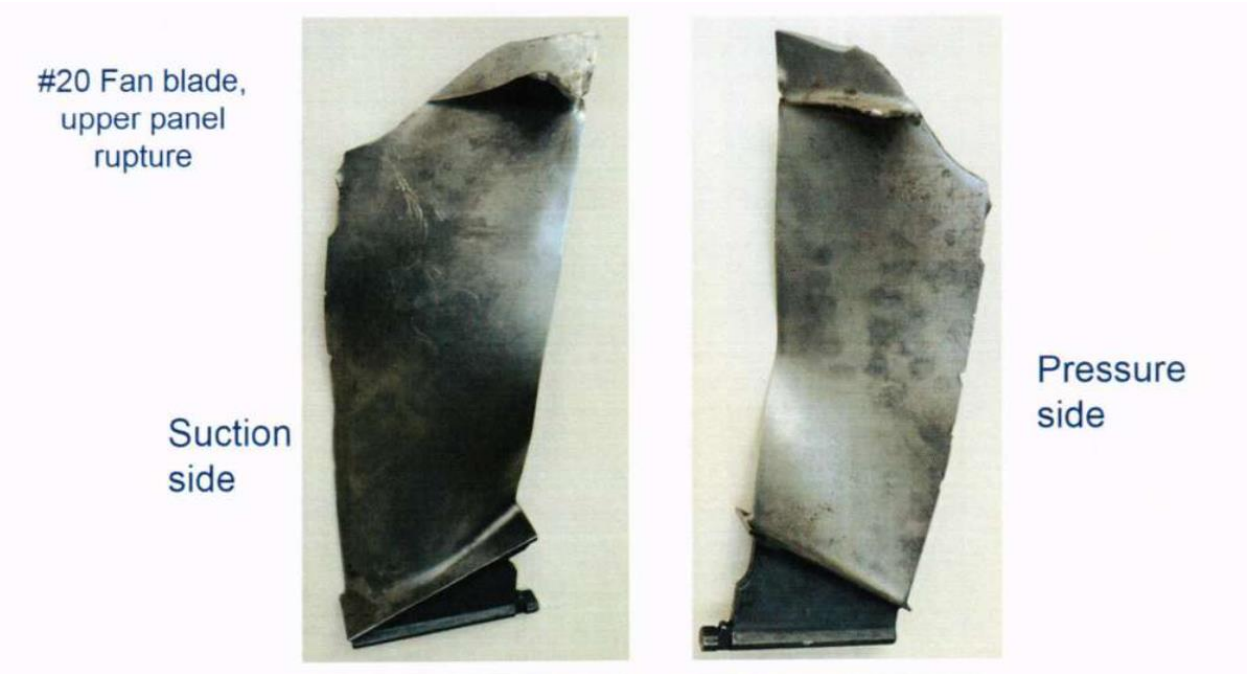



*Figure 50. Damage to fan blade No. 20 on the left engine*

A comparison between the fractures observed in this case and in previous cases of bird ingestion into this type of engine revealed the damage to be similar.[16]

Loose pieces of the fan blades caused damage to the fan case, including through-perforations.

[15] The materials supporting this conclusion were granted to the Commission during the investigation and were included in the draft final report. However, by demand of the state of manufacture and the engine manufacturer, this material was removed from the final draft of the report because it contained proprietary information unsuitable for publication.

[16] In particular, an event involving an A319 aircraft was analyzed, in which a similar separation occurred involving the outer 150 mm of fan blade No. 24 as a result of a collision with yellow-legged gulls.

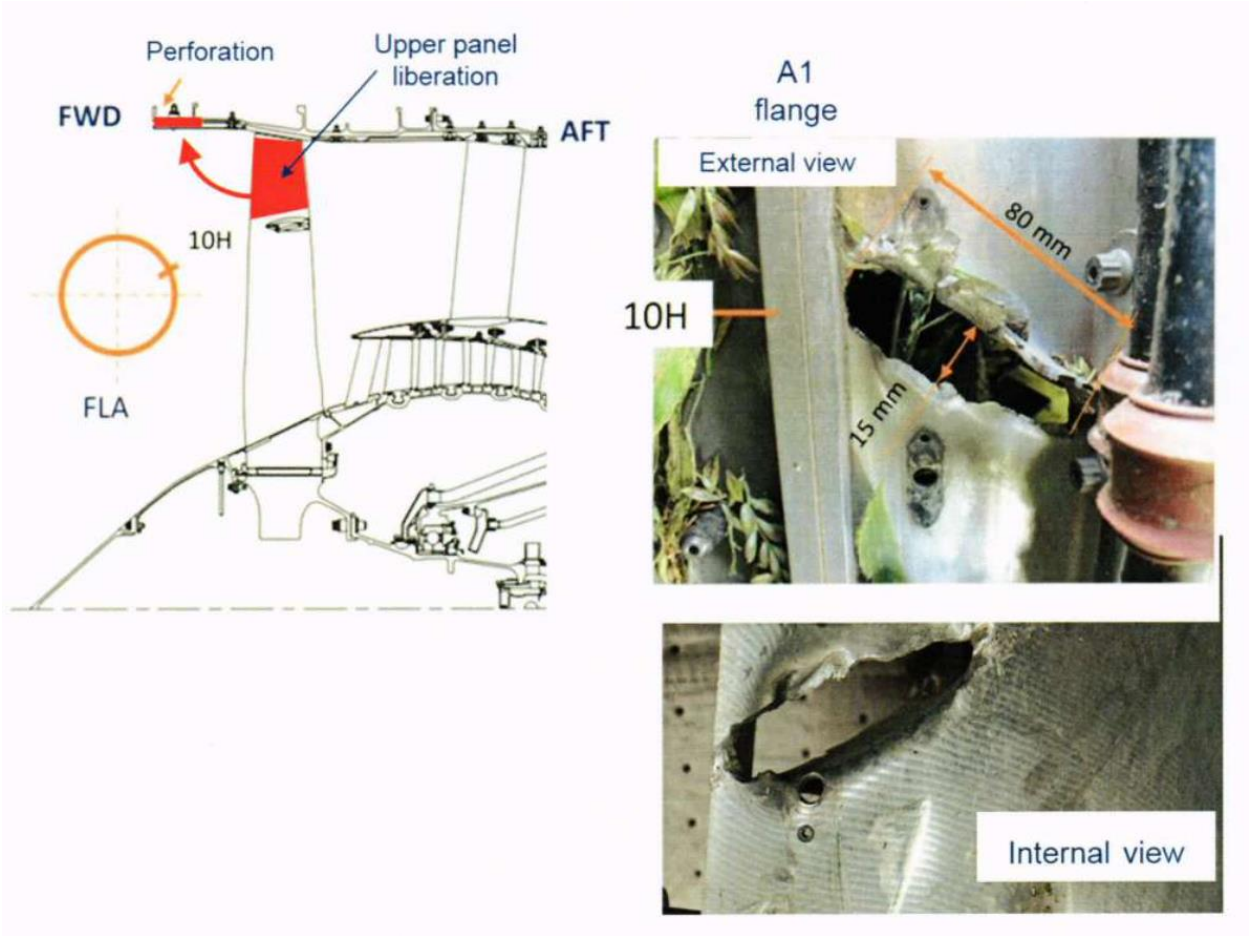



*Figure 51. Damage to the left engine fan case by a fan blade fragment*

The separated portion of the fan blade did not exit the fan case, so there was no uncontained failure (Fig. 52 and Fig. 53). This was confirmed by the absence of damage to the fan cowl opposite the perforation in the fan case. The separated portion of the fan blade did not pass through the observed perforation because of its size. Regarding this matter, the manufacturer explained that, in accordance with certification requirements, the fan case was constructed such that upon initial impact by high-energy objects from within (that is, the fan blades), the fan case will prevent them from exiting the engine even in the event that every fan blade separates.

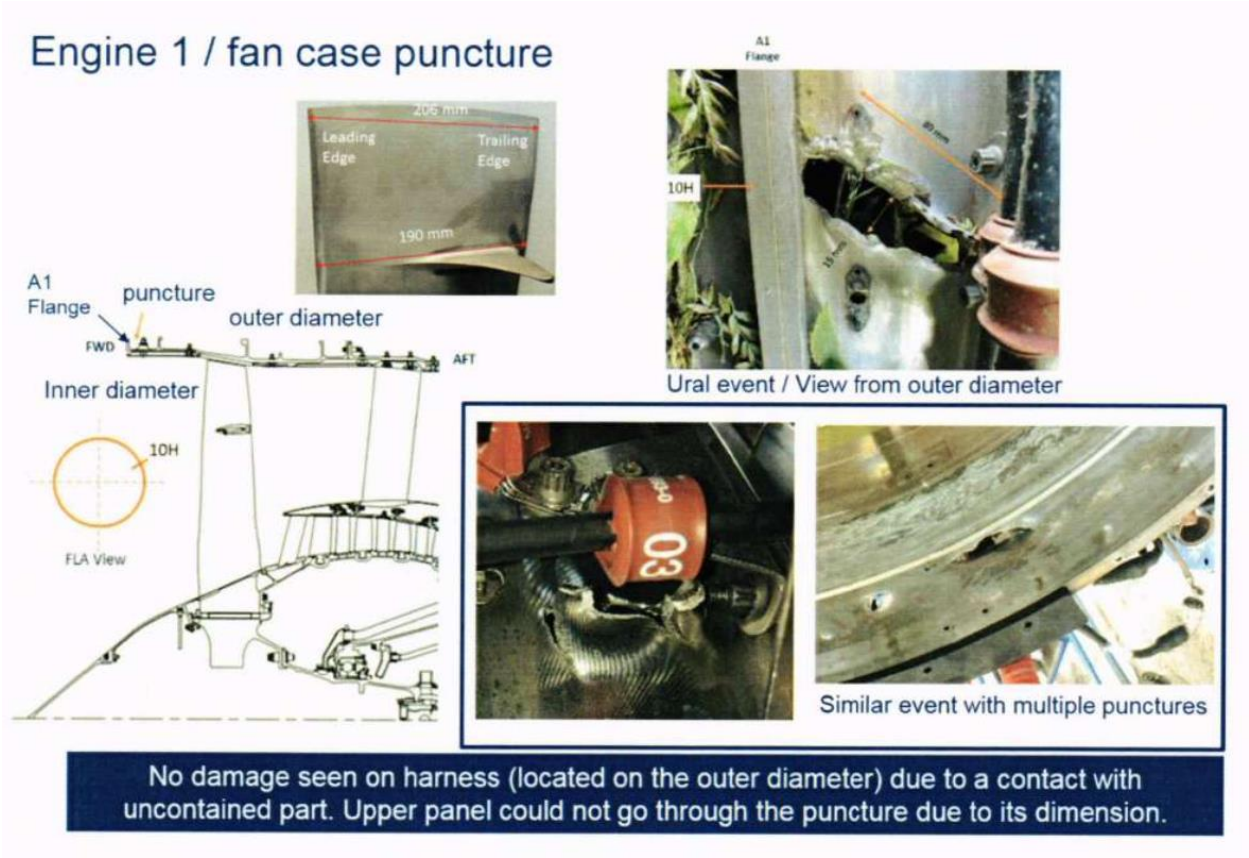



*Figure 52. Analysis of damage caused by the separated fan blade fragment*

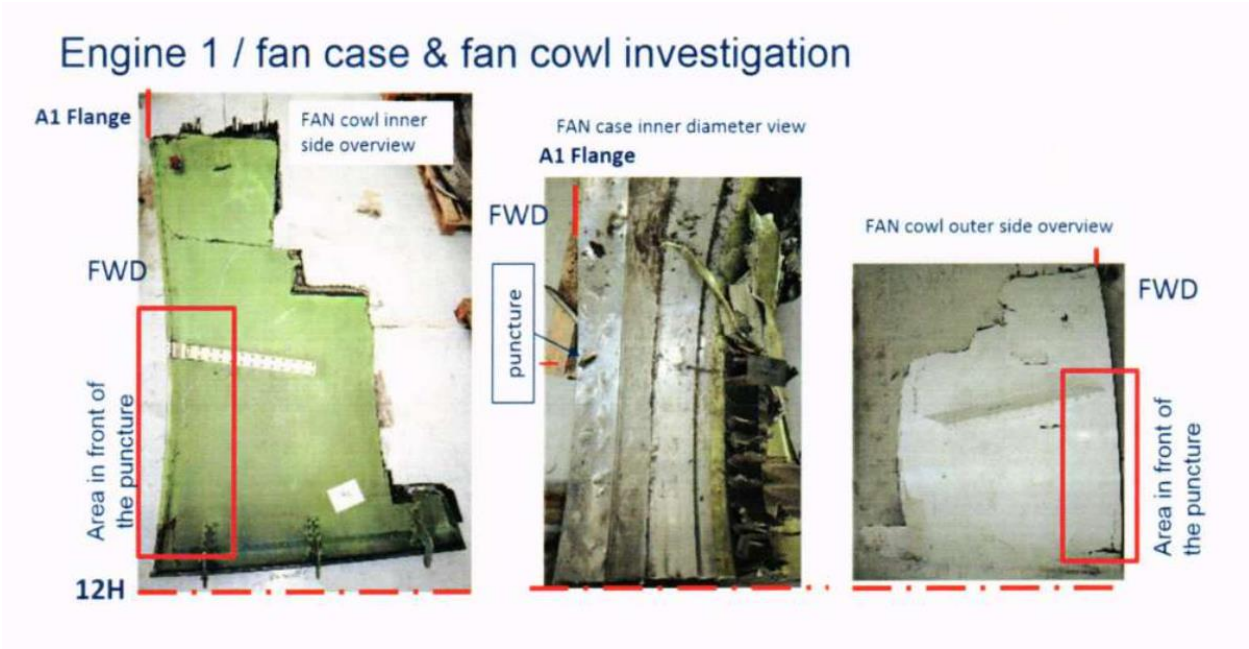



*Figure 53. Analysis of damage caused by the separated fan blade fragment*

During the examination of the left engine, bird fragments (feathers) were found on the T12 temperature sensor in the outlet guide vanes (OGV) (Fig. 54 and Fig. 55). The locations of these fragments on a diagram of the engine are shown in Fig. 56.

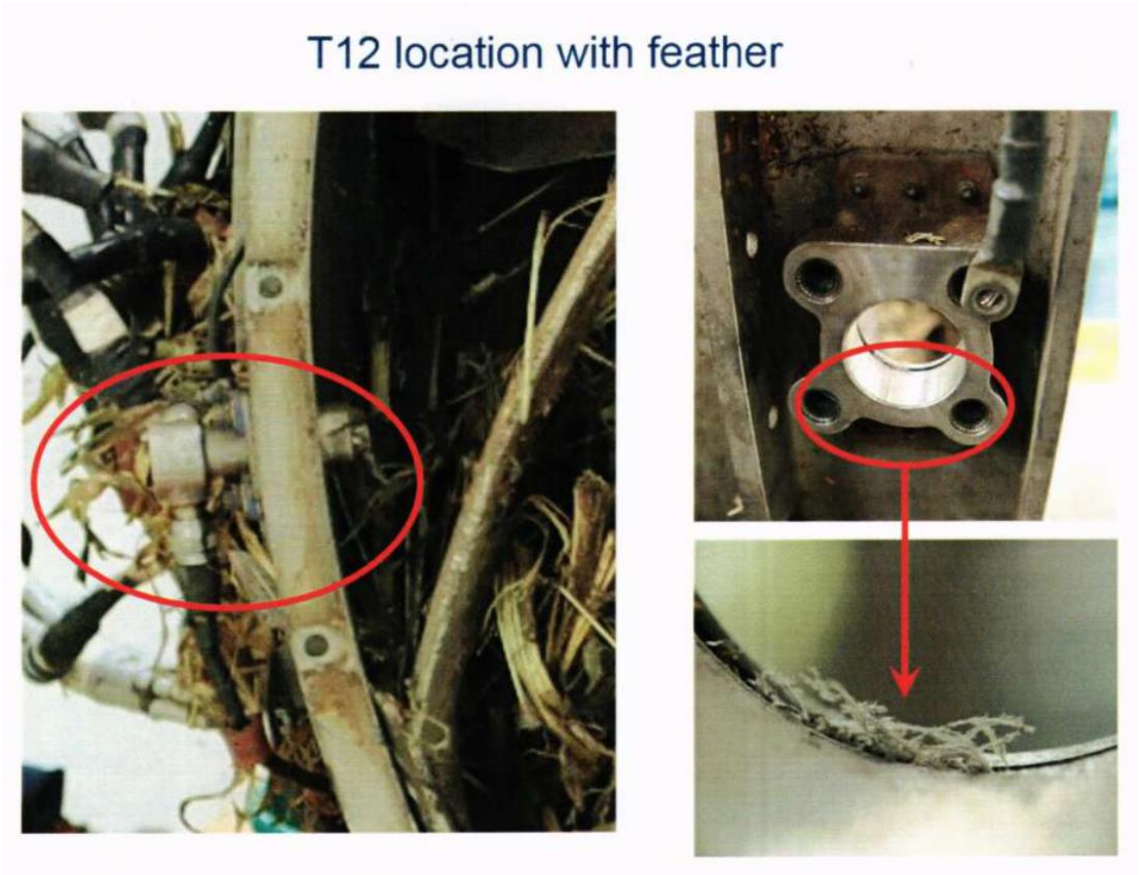



*Figure 54. Left engine T12 sensor location with fragments of feathers*

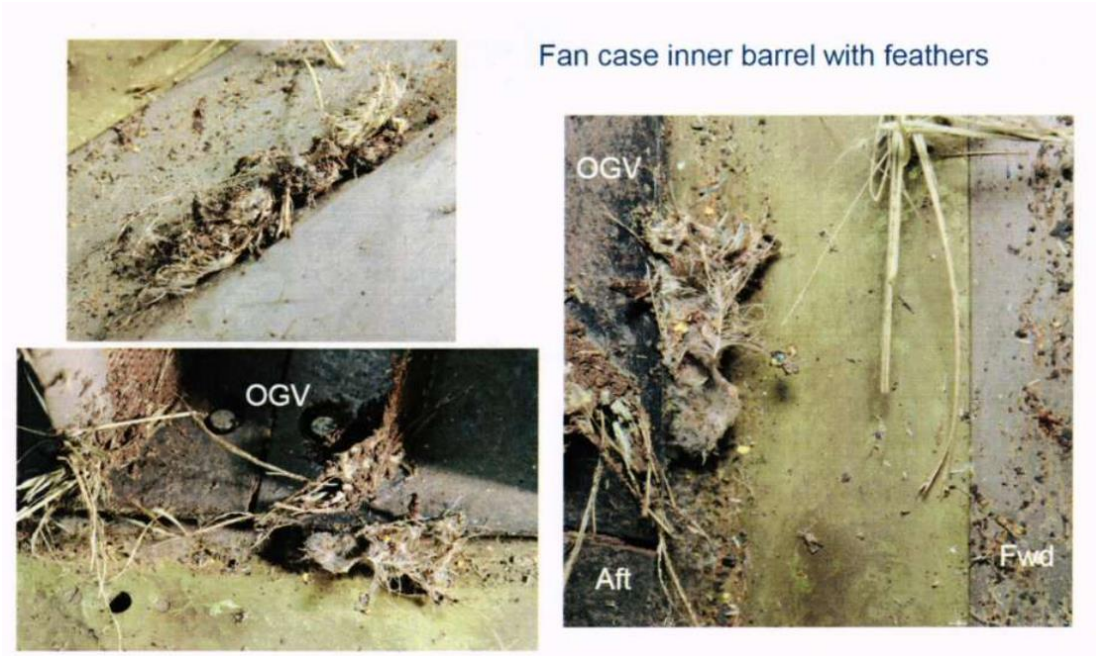



*Figure 55. Left engine outlet guide vane with fragments of feathers*

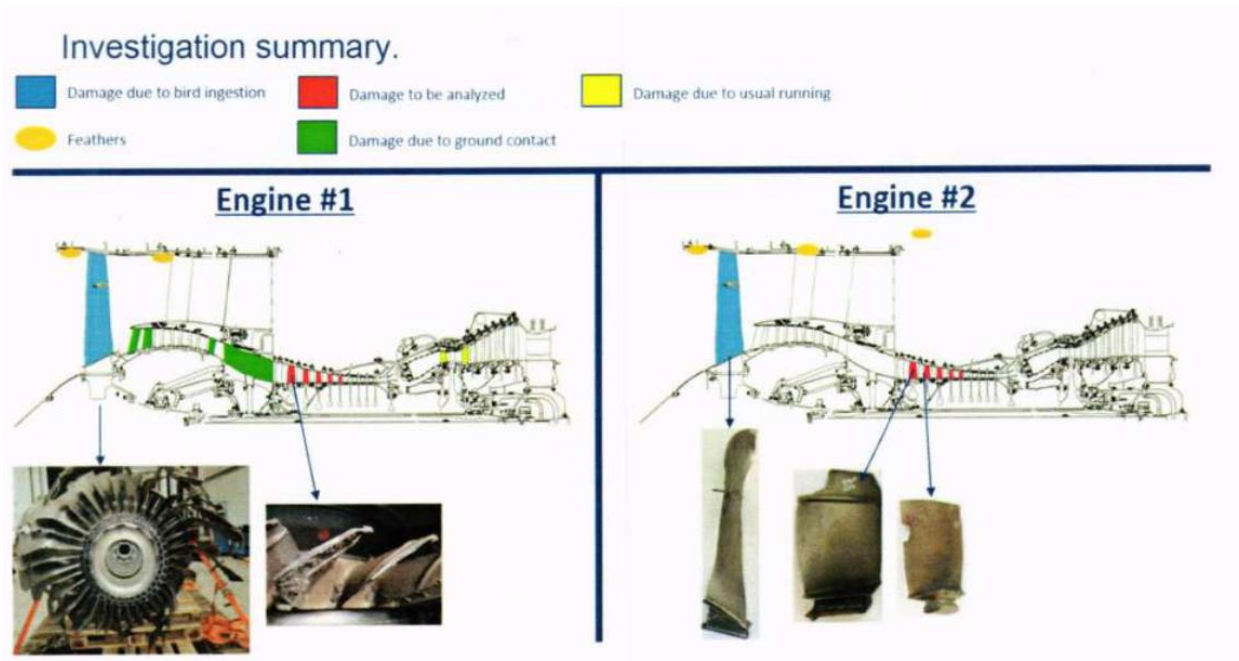



*Figure 56. Locations of various areas of interest on an engine diagram*

The examination of the left engine by the manufacturer produced the following basic conclusions:

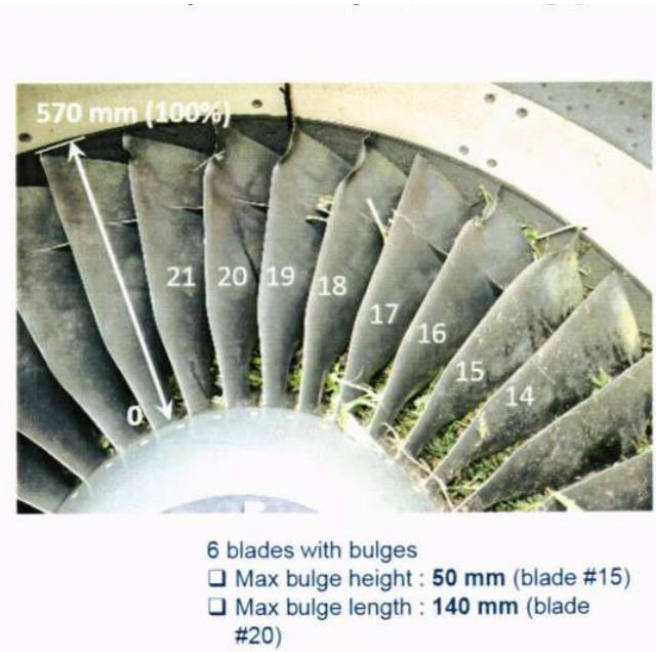
- Based on CFM's previous experience, the data show that the No. 1 engine ingested at least three birds, including at least one bird with a mass greater than 2.5 lbs (1.13 kg), which would be classified as a "large bird" according to the certification definition. Fan

blade No. 9 possessed a bulging deformation too large to have been the result of a collision with a “medium bird,” according to certification experience.

- After the bird strike, separated blade fragments remained within the fan case.

**Engine No. 2 (right, ESN – 697747)**

An analysis of the right engine identified one sector featuring traces of “soft body” impacts and deformation at about 85% span on blades 14 and 21, indicating that at least one bird impacted this sector, perhaps more. Supporting photographs and quantitative information about the deformations can be found in Fig. 57 and Fig. 58.




| Blade nbr | Bulge | | Tear location (mm) | Leading edge general deformation |
|---|---|---|---|---|
| | mm | % | | |
| 21 | 470 to 530 | 88 | 490 | NO |
| 20 | 400 to 540 | 82,5 | 455 | deformation |
| 19 | Length 130 | 87 | NO | 420<x<570 |
| 18 | Length 120 | 85 | NO | 400<x<570 |
| 17 | NO | | NO | Tip corner, bent |
| 16 | 125 | 86 | 450 | 415<x<570 |
| 15 | 110 | 81,5 | NO | 360<x<570 |
| 14 | NO | | 545 | NO |

*Figure 57. Location of damage and deformation on the right engine fan stage*

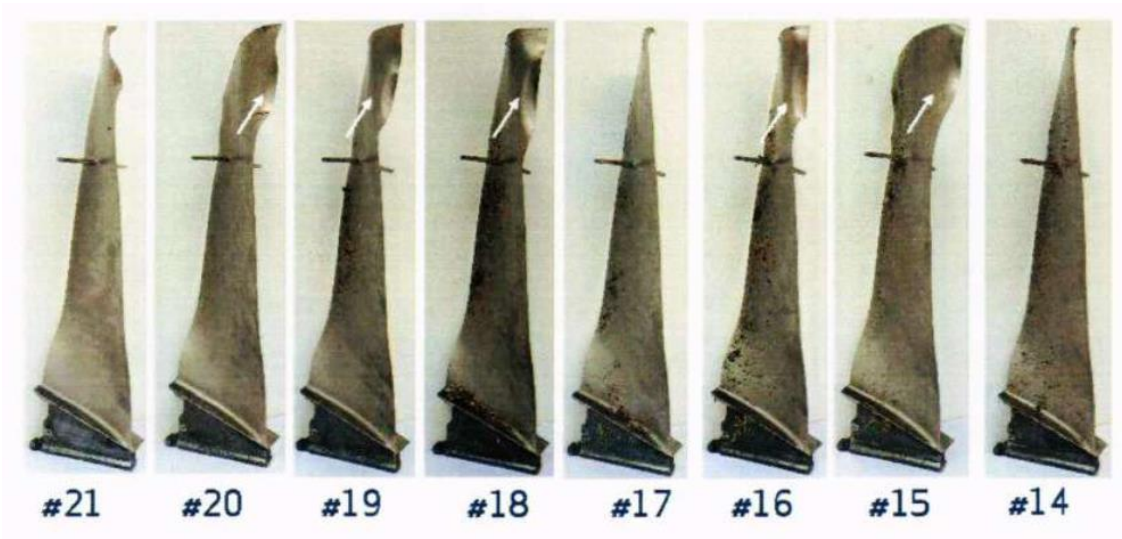



*Figure 58. View of damaged right engine fan blades*

A comparison of the present damage with damage observed during certification tests[17] showed that the blades suffered at least one impact at about 85% span by a bird with a mass greater than 1.5 lbs (0.68 kg), and perhaps (judging by the length of the bulges) greater than 2.5 lbs (1.13 kg). It was noted that the damage observed during certification tests for birds of this size was usually more significant than damage incurred in service. The birds launched during the tests have a greater density because they are wrapped according to the specifications of the test cannons.

As was the case on the left engine, bird fragments (feathers) were found on the T12 sensor and on portions of the exterior (see Fig. 56 and Fig. 59).

*Figure 59. Bird fragments (feathers) on portions of the exterior of the right engine*

The manufacturer's examination also included an analysis of the magnitude of the loss of thrust of the right engine and the possible reasons for this loss, as well as the reasons for this engine's compressor stall in the TO/GA regime. The basic conclusions of this analysis are included later in this section.

[17] The materials supporting this conclusion were granted to the Commission during the investigation and were included in the draft final report. However, by demand of the state of manufacture and the engine manufacturer, this material was removed from the final draft of the report because it contained proprietary information unsuitable for publication.

**Determination of the Probable Cause for the Reduction in Commanded $N_1$ on the Right Engine After the Bird Strike**

The FDR data showed that after the bird strike, the commanded $N_1$ on the right engine fell by 3% even though the thrust lever did not move. The actual $N_1$ after restoration of normal operation (following the transitory phase associated with bird ingestion) corresponded to the commanded $N_1$. This reduction in the commanded right engine $N_1$ by 3% following bird ingestion was probably caused by the following:

- The impact of a bird with a mass greater than 1.5 lbs (not excluding an impact of a bird with a mass greater than 2.5 lbs) against fan blades 14 through 21.
- The rupture (loss of pressure)[18] of a pneumatic tube in the vicinity of the PS12 sensor (Fig. 60) inside the fan compartment (probably as a result of a mild unbalanced condition in the fan stage).
- An increase in pressure of 1.5–2 psi at PS12 practically up to the pressure in the fan compartment (P0), resulting in the static pressure signal shifting from the aircraft sensors to the engine sensors.[19]

[18] The possibility of a leak appearing in precisely this location, leading to the observed decrease in commanded $N_1$, was established based on the results of modeling and schematic analysis. Upon examination of the recovered engine fragments after the accident, the precise location of the leak was not determined. A significant portion of the relevant assembly was destroyed in the accident.

[19] Two measurements of static pressure are transmitted to the engine control block from two separate aircraft systems (ADC1 and ADC2), while another two are transmitted directly from the engine (a two-channel sensor). Under normal conditions, the calculation of the commanded $N_1$ uses data from the "aircraft" system (ADC1). In the event of a deviation in the measured pressure, according to its predetermined logic, the data source will shift either to ADC2 or to the engine's own sensor. On the left engine, the commanded $N_1$ value following the collision with birds did not change, therefore no such transfer to the engine sensors occurred.

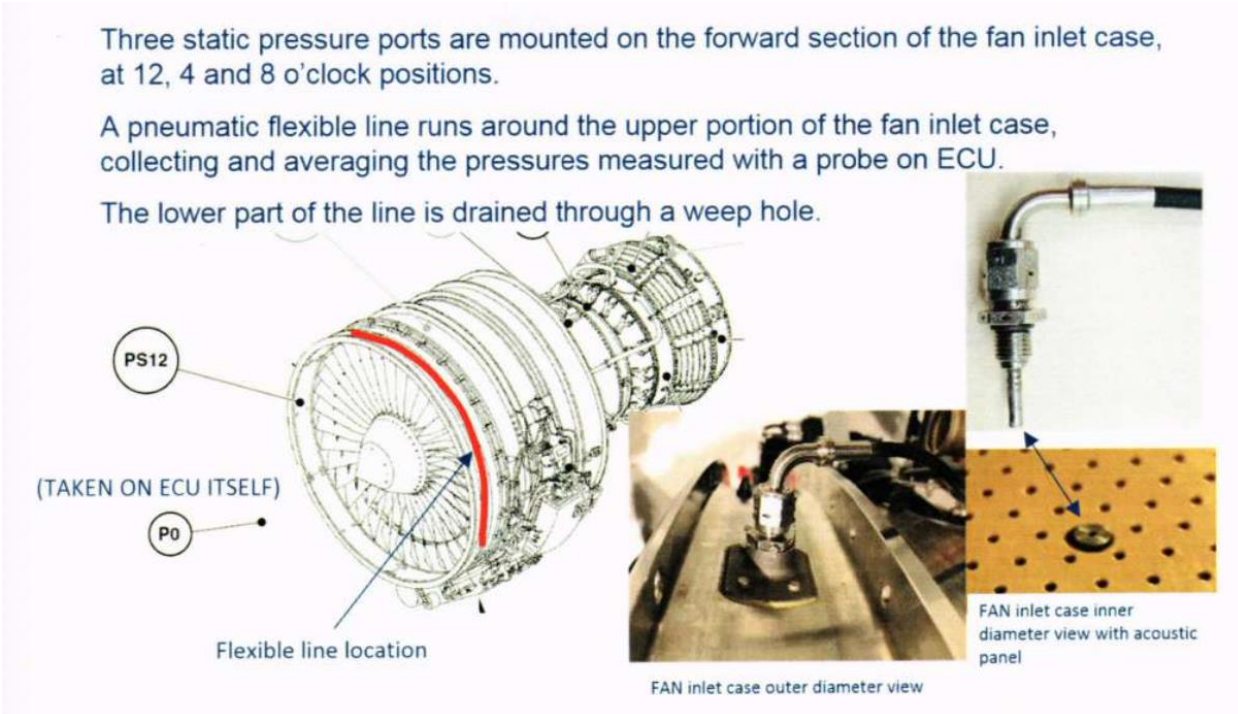



*Figure 60. Diagram of the static pressure sensor (PS12) on the engine inlet*

By the engine manufacturer's assessment, the 3% decrease in commanded $N_1$ resulted in a 9-10% loss of thrust below the FLEX 49 regime on the right engine.

According to the data presented by the engine manufacturer, during the entire operational history of the -5B family of engines (with a total flight time of 234 million hours), eight cases had been identified involving a failure of the PS12 sensor, accompanied by a difference in $N_1$ between the left and right engines. None of these cases involved ingestion of birds.

**Determination of the Probable Cause of the Right Engine Compressor Stall Following the Application of TO/GA Power by the Crew**

The low pressure compressor did not have any visible damage. Upon examination of the high pressure compressor, damage was found in the form of missing tip corners on seven blades (Fig. 61), and one blade was bent. Several blades had traces of what was most probably adhered material between the blade tip and blade body. Nicks and dents were also observed on the second stage high pressure compressor blades.

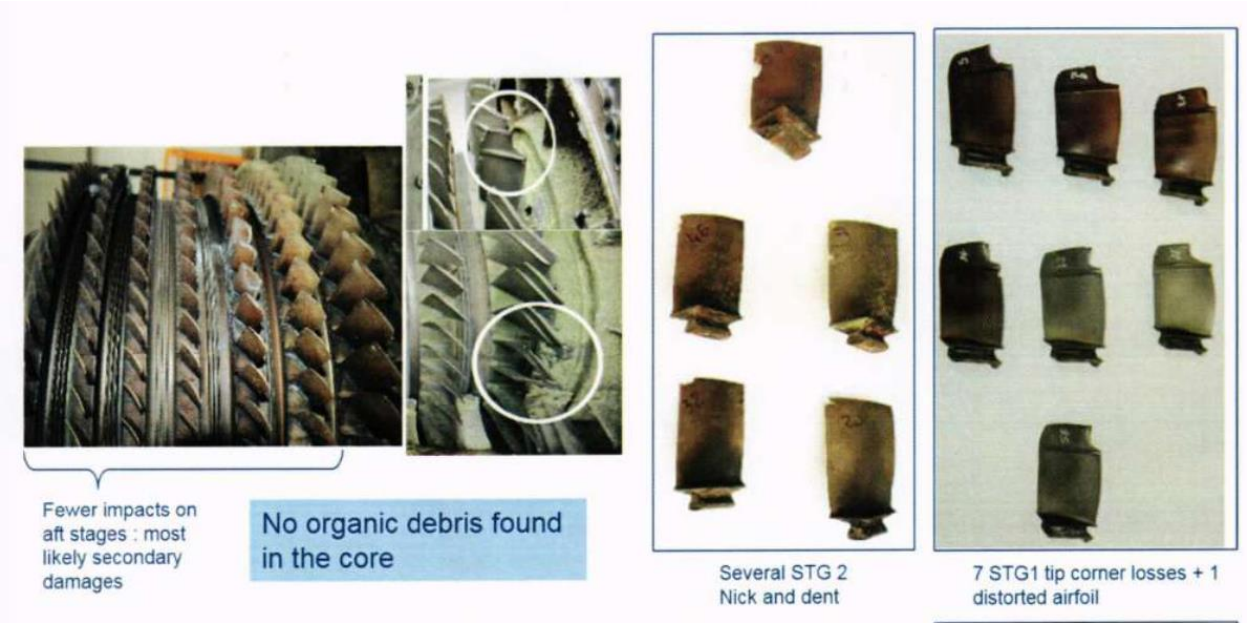



*Figure 61. Condition of elements of the right engine high pressure compressor*

The engine manufacturer analyzed a number of in-service cases involving engine compressor stalls caused by damage to the first stage high pressure compressor blades, including damage as a result of bird strikes. The most similar incident is shown in Fig. 62. In that case, following a bird strike, a compressor stall occurred, accompanied by heavy vibrations. Upon examination, it was found that the high pressure compressor blades had sustained damage similar to that found in the subject incident. The engine was removed from service.

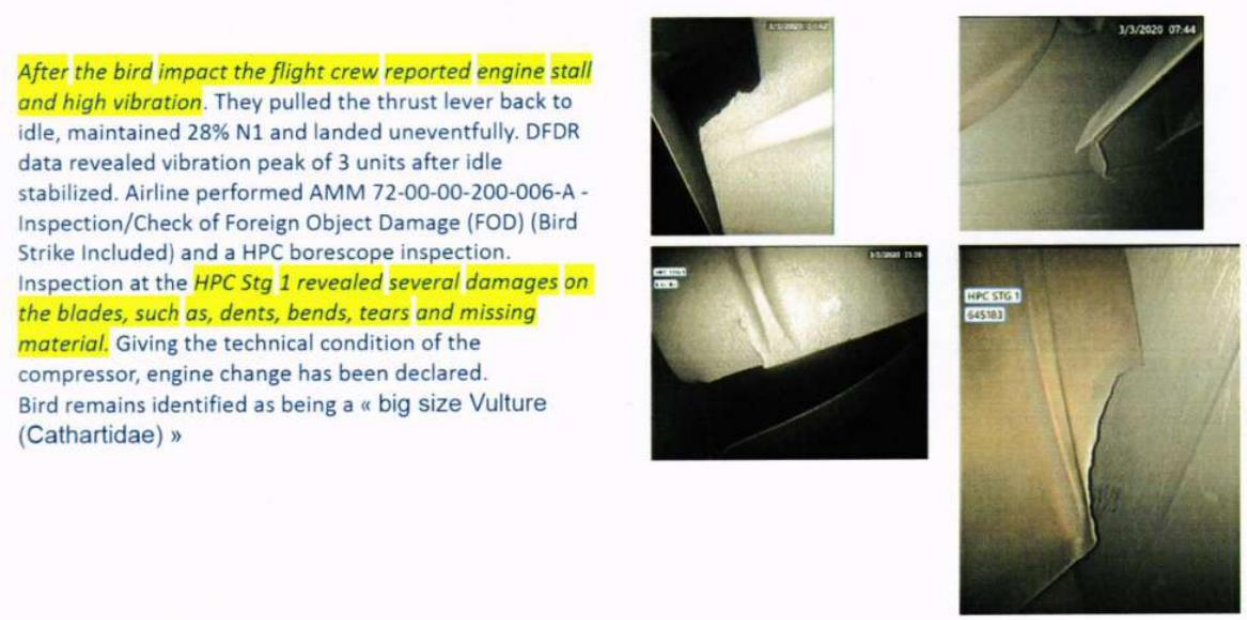



*Figure 62. Consequences of bird ingestion into the engine core in a previous incident*

Based on the analysis of in-service incidents, it was found that ingestion of birds into the engine core can lead to deformation of the first stage high pressure compressor blades.

Deformation of the first stage high pressure compressor blades did not lead to compressor stalls in all cases. Cracks and nicks in the blades are not directly associated with a compressor stall.

The engine manufacturer explained that the compressor stall after the pilots applied TO/GA power during the accident flight occurred for the following reasons:

1. The bird ingestion led to deformation of the first stage high pressure compressor blades.
2. The airflow through the compressor was disrupted as a result of the deformation of the blades, which led to:
    - stall in TO/GA regime
    - overloading of the blades by dynamic bending action.
3. Rubbing of the blade tips against the case due to disrupted airflow in the compressor, vibrations, and/or excessive loading, resulting in the appearance of cracks in the upper corners.
4. Growth of the cracks and separation of the upper corners under vibratory action.

An illustration of this process, which occurred in the right engine following the application of TO/GA power by the crew, is shown in the diagram in Fig. 63. The compressor stall occurred at the end of the process of responding to the throttle command for 95% $N_1$. The reduction in $N_1$ occurred as a result of disrupted airflow with subsequent recovery to an $N_1$ value of 80%, followed by repeated increases up to the commanded value and frequent repetition of the cycle.

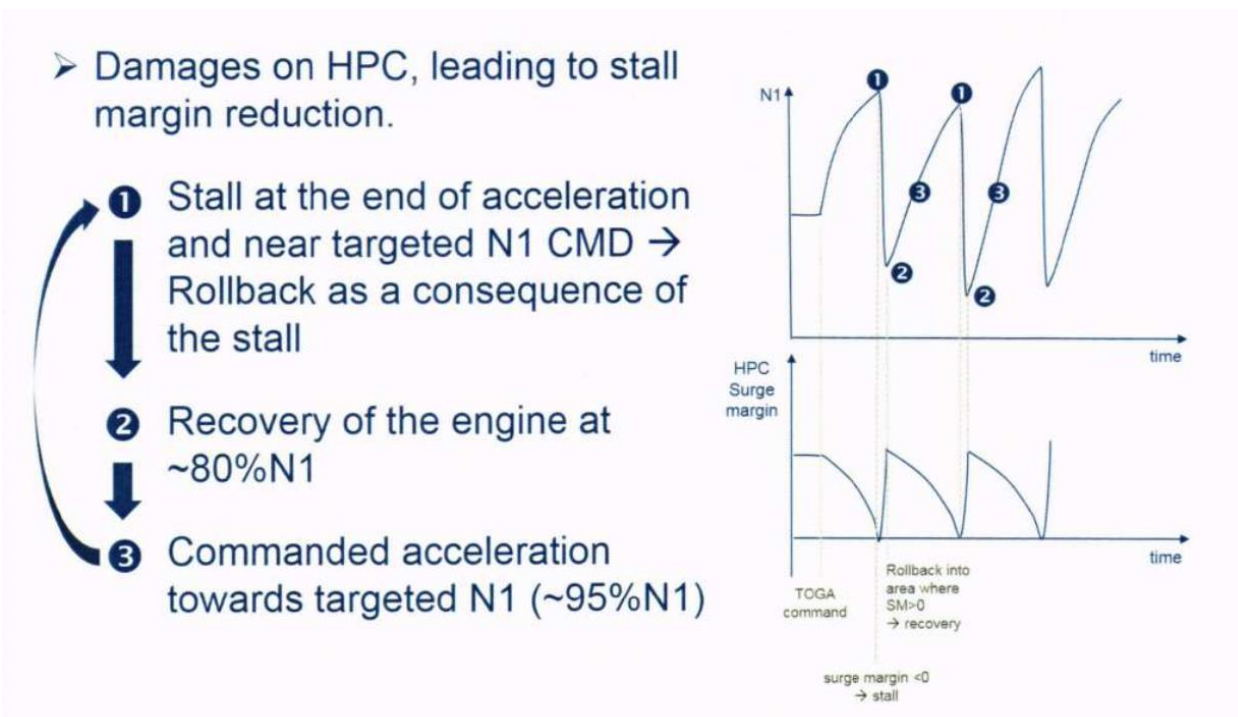



*Figure 63. A diagram illustrating the process taking place in the right engine after the application of TO/GA power*

Regarding the right engine, the following scenarios were considered most likely:

- Ingestion of a bird with a mass greater than 1.5 lbs (perhaps greater than 2.5 lbs) at the 85% span of the fan blades.
- Ingestion of another bird into the engine core, leading to deformation of the edges of the first stage high pressure compressor blades (it was not possible to determine the weight of the bird that entered the core).
- The deviation in the commanded $N_1$ value probably occurred because of a leak in the PS12 pneumatic tube and the equalization of the pressure values at PS12 and P0. This scenario cannot be proven by empirical data, because the engine control block and its supply lines were destroyed when the aircraft struck the ground.
- The regular cycle is most likely explained by the disruption of airflow into the compressor following the placement of the thrust lever into the TO/GA regime, as a result of the deformation of the first stage high pressure compressor blades due to bird impact.

The loss of thrust on the right engine (relative to the FLEX 49 regime) from the established regime (that is, after the reestablishment of rotation following the bird ingestion but before the application of TO/GA power) due to mechanical damage and the reduction in the commanded $N_1$ value was assessed at around 20%, with the role of the two aforementioned factors being approximately equal.

### 1.16.4. Mathematical Modeling

#### 1.16.4.1. Determination of Rudder Pedal Forces

The pedal forces are not recorded by the DFDR. As a result, the aircraft manufacturer calculated the forces based on the recorded deflection of the pedals and the rudder trim system. It should be noted that if the trim system is deflected in a direction opposite to the pedals for any reason (for example, due to inputs by the autopilot), then the forces on the pedals will increase.

The results of the calculations are shown in Fig. 64. Because the actual mechanical characteristics of the rudder system on the accident aircraft were unknown, calculations were conducted based on three scenarios:

1. Minimal pedal forces: the lowest tension in the control cables + the lowest feedback from the Artificial Feel Unit (AFU) + the least friction (the results of this calculation are shown in yellow).
2. Maximum pedal forces: the highest tension in the control cables + the highest feedback from the AFU + the most friction (the results of this calculation are shown in blue).
3. Moderate pedal forces: the mathematical mean of the first two extremes (the results of this calculation are shown in green).

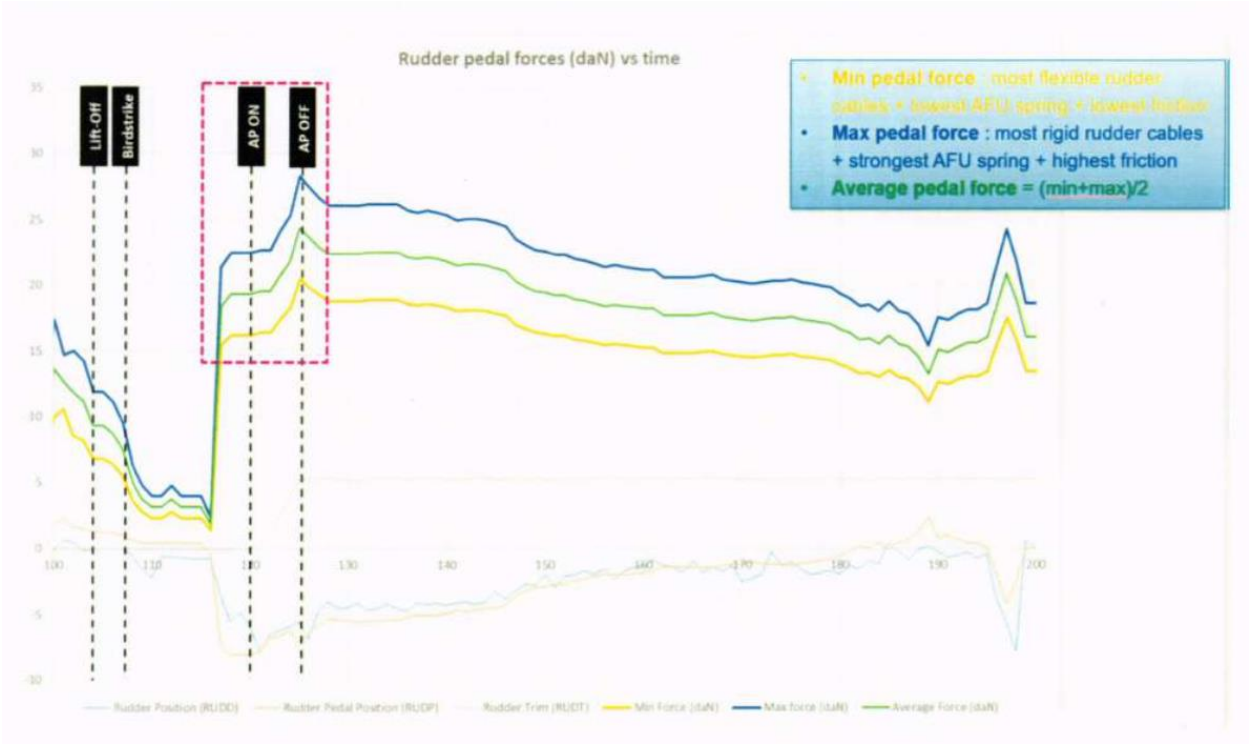



*Figure 64. Results of the pedal force calculations*[20]

### 1.16.4.2. Determination of the Magnitude of the Loss of Thrust after Bird Strike

A thrust analysis of both engines following the bird strike was conducted by the aircraft manufacturer based on its own experimental data (see section 1.16.3 of this report).

Engine No. 1 continued to operate after the bird strike; no in-flight shutdown was recorded (see Fig. 37 and Fig. 38). There was a significant loss of thrust, which was estimated to be ≈40% based on actual $N_1$ speed. Upon advancement of the thrust lever to the TO/GA regime, the left engine did not respond. After the thrust lever was placed into the idle regime, the actual $N_1$ speed decreased normally to the flight idle position (≈29%).

Engine No. 2 also continued to operate after the collision with birds, albeit with some loss of thrust (see Fig. 37 and Fig. 38). The loss of thrust occurred for two reasons: a decrease in the commanded $N_1$, and mechanical damage to elements of the fan and the high pressure compressor.

The commanded $N_1$ was recorded by the DFDR within a margin of error of 2%. Following the bird strike, the commanded $N_1$ parameter decreased to 88%. Because it was clear from the recorded data that the actual $N_1$ speed of the left engine tracked the commanded $N_1$, this value was used in order to conduct a more precise calculation of the size of the loss of thrust due to the decrease in commanded $N_1$. The total decrease in $N_1$ was around 3%, which corresponds to ≈10% of the thrust in the FLEX 49 regime.

The size of the loss of thrust due to damage to the fan was calculated by the engine manufacturer based on the instantaneous fuel flow and outlet gas temperature parameters. The

[20] Force values in this chart are indicated in decanewtons (daN). 1 daN is approximately equal to 1 kg/s.

calculations showed that the possible loss of thrust was ≈10% for each specific $N_1$.[21] This calculation was satisfactorily supported by both the recorded and modeled parameters.

Finally, the total distribution of thrust from the two engines was calculated, and a comparison was made with certain nominal values (Fig. 65).

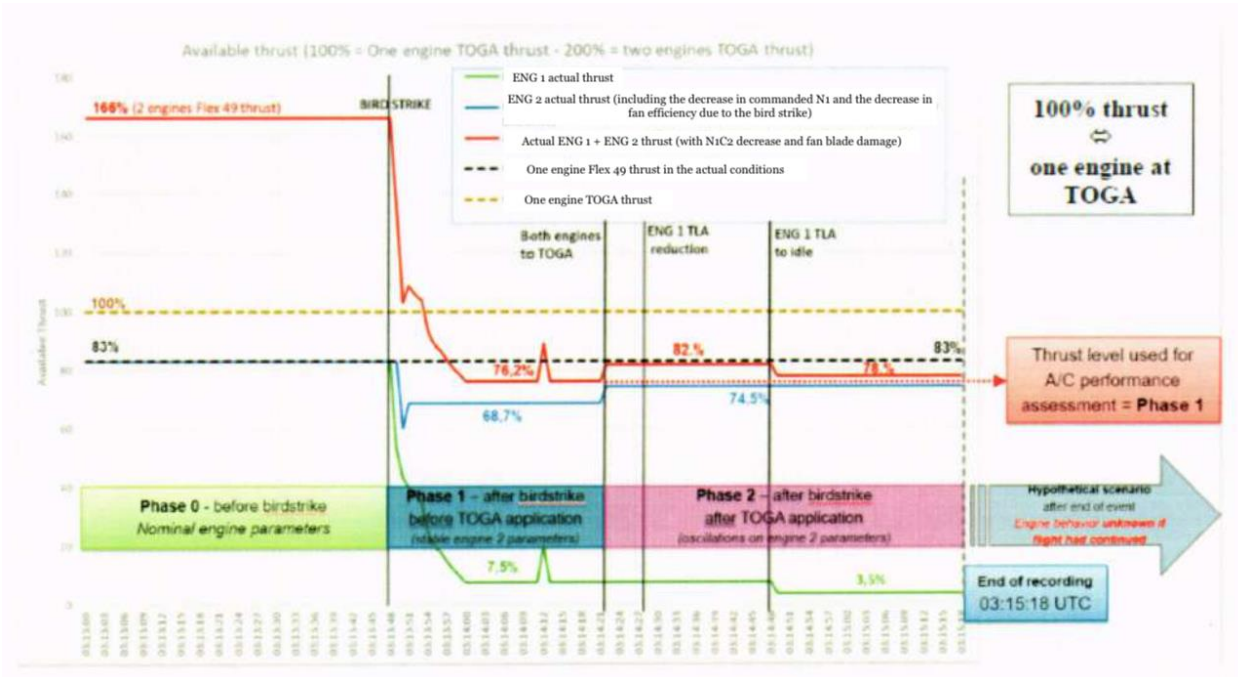



*Figure 65. Determination of engine thrust*

The following conclusions can be drawn from this graph:

- Prior to the bird strike, the thrust from both engines was consistent with the FLEX 49 regime, or 83% of TO/GA thrust.
- After the bird strike but before the application of TO/GA power, the total calculated thrust from both engines fell to 76.2%, which is less than the thrust provided by one functioning engine in the FLEX 49 regime (83%).
- After both throttles were advanced into the TO/GA regime, the total calculated thrust increased to 82%, which is practically equal to the thrust provided by one functioning engine in the FLEX 49 regime.
- After this, as the No. 1 engine was placed in the idle position, the total calculated thrust decreased to 78%.

### 1.16.4.3. Analysis of the Possibility of Continued Flight with Available Engine Thrust

Taking into account the total thrust values for both engines, stabilized ground gradient functions were developed for scenarios involving both retracted and deployed landing gear (Fig.

[21] Translator's note: the intent of the phrase "для каждого конкретного $N_1$" (literally "for each specific N1") is unclear.

66). The calculations assumed that the total available thrust corresponded to phase 1 on Fig. 65; that is, 76.2% of the thrust of one functioning engine in the TO/GA regime. The calculated beta target was also maintained throughout the model (see section 1.18.1. of this report).

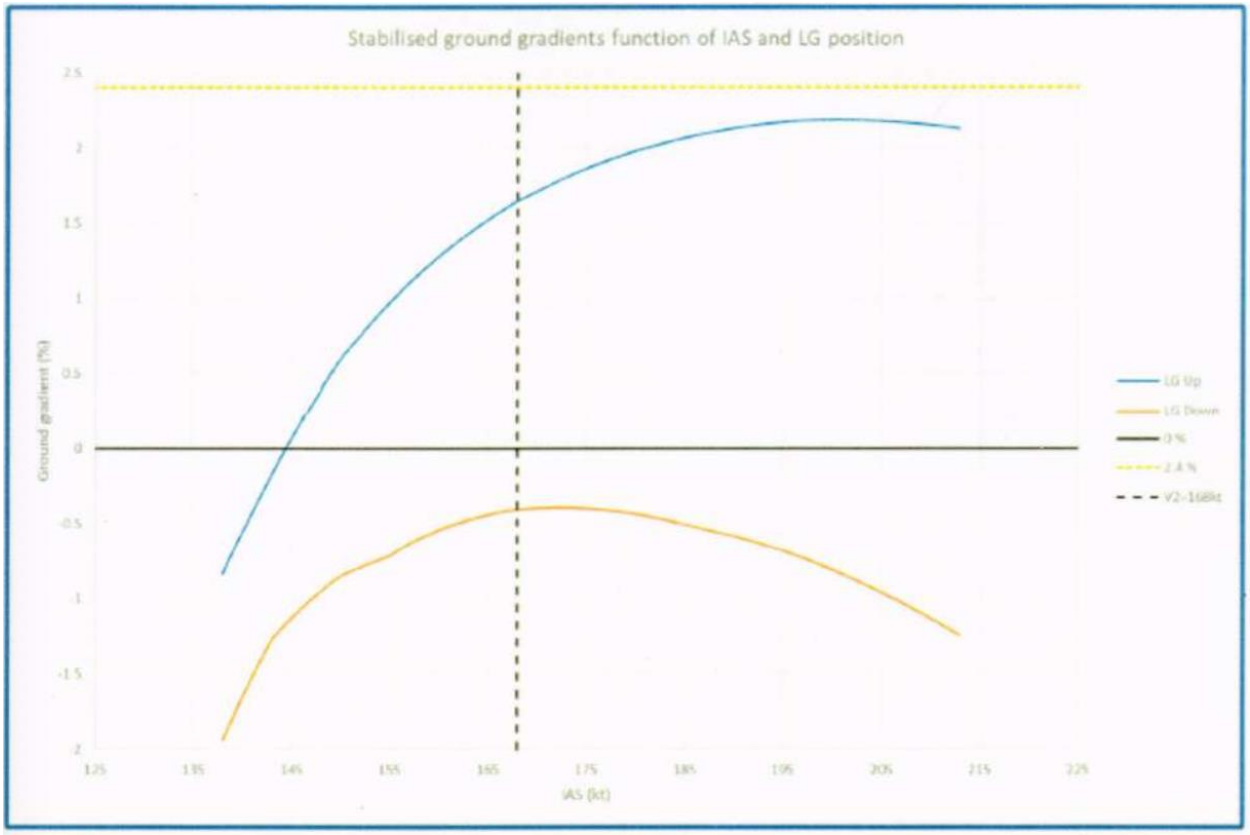



*Figure 66. Stabilized ground gradients function*

The results of the model showed that with the landing gear extended (orange), the stabilized ground gradient was negative for all tested airspeeds. In other words, the aircraft could not maintain altitude in this configuration without losing airspeed.

With the landing gear retracted (blue), the stabilized ground gradient had positive values. The magnitude of the gradient was ≈1.65% for a speed of 167 kt (the calculated $V_2$ speed for the accident flight). With an increase in speed, the stabilized gradient increased to ≈2.05% for a speed of $V_2$ + 15 kt, but remained below the minimum certification requirement of 2.4%.

The trajectory of the flight was also calculated in terms of the glide path ratio which could be achieved while operating the airplane according to the FOM. For the purposes of the calculation, the flight was divided into four segments, chosen based on the criteria in the table below. The total thrust in segments 2-4 corresponded to phase 1 in Fig. 65; that is, prior to the application of TO/GA power.

<table>
<tr><th>No.</th><th>Segment starting criterion</th><th>Segment ending criterion</th><th>Airspeed</th><th>Landing gear position</th><th>Total theoretical thrust/without loss of thrust</th><th>Glide path ratio</th><th>Loss due to additional drag</th></tr>
<tr><td>1</td><td>failure</td><td>failure + 3 s</td><td>178 knots at segment start</td><td>extended</td><td>2 engines on FLEX 49</td><td>1% (according to DFDR)</td><td>0</td></tr>
<tr><td>2</td><td>failure + 3 s</td><td>airspeed = $V_2$</td><td>decreased to $V_2$</td><td>extended</td><td rowspan="4">remaining total thrust for phase 1 (76% of TOGA)</td><td>5% (fixed)</td><td rowspan="4">calculated based on modeling</td></tr>
<tr><td>3</td><td>airspeed = $V_2$</td><td>landing gear retracted</td><td rowspan="2">$V_2$</td><td>in transit</td><td rowspan="2">calculated</td></tr>
<tr><td>4</td><td>landing gear retracted</td><td>end of flight data recording</td><td>retracted</td></tr>
</table>

The results of the model are shown in Fig. 67.

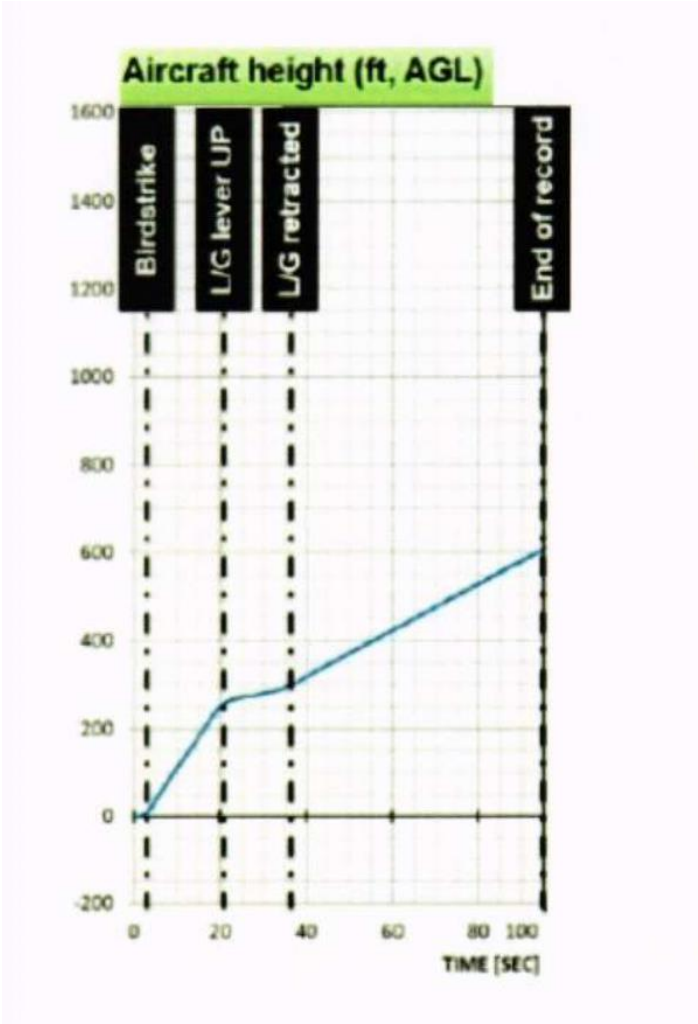



*Figure 67. Calculated flight profile (modeled)*

It is apparent from the graph that in this scenario, the aircraft could have been at a height of 600 feet at the moment when it in fact impacted the ground, assuming that engine thrust did not change during the time period under consideration.

### 1.16.5. Investigation of Avionics

Several computer systems were taken from the aircraft in order to transcribe the data from their non-volatile memory (NVM), including the Centralized Fault Display Interface Unit (CFDIU); the No. 1 and No. 2 Engine Interface Units (EIUs), the Engine Vibration Monitor (EVM); the No. 1 and No. 2 Flight Control Data Concentrators (FCDCs); the No. 1 and No. 2 Flight Augmentation Computers (FACs); the No. 1, No. 2, and No. 3 Spoiler-Elevator Computers (SECs); the No. 1 and No. 2 Elevator Aileron Computers (ELACs);[22] and the No. 1 and No. 2 Flight Management and Guidance Computers (FMGCs).

[22] *Translator's note: the report uses the English acronym "FLAC" without providing a breakdown of what each letter stands for. In most cases, searching Airbus documentation easily turned up the original English source of similar acronyms, but this did not work for "FLAC." An educated guess was made that "FLAC" was intended to be "ELAC," or Elevator Aileron Computer, whose absence from this list would otherwise be notable.*

By decision of the Commission (and with the agreement of the representatives of the BEA, Airbus, and CFM), the CFDIU and EIUs 1 and 2 were subjected to intensive examination. The remaining systems were not examined because the information they contained was already available to the Commission.

**Results of the EIU Examination**

The examination was conducted in the BEA laboratory. The data from the NVM of EIU 1 were successfully downloaded. The data from the NVM of EIU 2 could not be downloaded because of mechanical damage to the microchip.

Data from the accident flight were not registered in EIU 1. This occurred because the transfer of data from the volatile to non-volatile memory takes place at the end of the flight when the engines are shut off ($N_2$ <20%). This condition was not met during the accident flight. It should be noted that the EIU is not designed to be used for investigating accidents.

**Results of the CFDIU Examination**

The NVM circuit board from the CFDIU was sent to the BEA and installed into a Post Flight Report (PFR) reading device. The PFR download took place at the headquarters of manufacturer Thales Avionics. The PFR was successfully downloaded, allowing the recovery of all ECAM messages and system fault messages that were registered during the accident flight. The results of the transcription are shown in Fig. 68.

```
A/C ID    DATE    GMT    FLTN      CITY PAIR
VQ-BOZ    15AUG   0400   SVR178    UUBW URFF


+-----------------------+
:    MAINTENANCE        :
: CURRENT FLIGHT REPORT :
+-----------------------+

A/C ID   DATE    GMT         FLTN      CITY PAIR
.VQ-BOZ  15AUG   0310/      SVR178    UUBW URFF

WARNING/MAINT.STATUS MESSAGES
-----------------------------
GMT  PH ATA
0310 02 77-00 ENG 2 FADEC
0313 05 77-00 ENG 1 REVERSE UNLOCKED
0313 05 77-00 ENG 1 PROBES FAULT
0314 05 22-00 AUTO FLT AP OFF
0314 05 77-00 ENG 1 STALL
0314 05 77-00 ENG 1 EGT OVER LIMIT
0314 05 77-00 ENG 1 STALL
0314 05 77-00 ENG 1 EGT OVER LIMIT

FAILURE MESSAGES
----------------
GMT  PH ATA                                SOURCE    IDENT.
0310 02 22-83-34 AFS:FMGC2                  AFS
0311 02 23-51-34 AMU (1RN)                  AMU
0311 02 75-21-10 HPTC VLV(POS), HMU ENG2A   EIU2FADEC
0314 05 73-21-40 T12 SNSR, J9, ECU  ENG1A   EIU1FADEC
0314 05 73-21-40 T12 SNSR, J9, ECU  ENG1A   EIU1FADEC
0314 05 78-31-00 TR LATCH, STOW SW  ENG1A   EIU1FADEC
0314 05 78-31-00 TR LATCH, STOW SW  ENG1A   EIU1FADEC
```

*Figure 68. Accident flight PFR*

A table, shown in Fig. 69, was created based on the results of an analysis of the data and a comparison of the data with the aircraft manufacturer's control data. The table includes all generated ECAM messages, as well as information about whether it was related to the events under investigation and whether it was presented to the crew. It should be noted that the time of generation for each message is accurate only to the nearest minute.

| PFR WARNING/MAINT. STATUS MESSAGES | | | | | | | PFR FAILURE MESSAGES (CORRELATED) | | | | | ADDITIONAL CORRELATIONS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GMT | PH | ATA | Type | Title | Alert Type | Displayed to crew? | GMT | PH | ATA | Failure Message (FM) Title | Comment | DFDR | ACMS report | NVM ECU |
| | | | | *No alert* | | | 0310 | 02 | 22-83-34 | AFS: FMGC2 | Not relevant for the event as FG2 OK (FD2 available). Most probably due to electrical transient at aircraftpower-up. | FD2E=1 since beginning of the recording | N/A | N/A |
| | | | | *No alert* | | | 0311 | 02 | 23-51-34 | AMU (1RN) | Not related to the event (COM system), present since LEG05. | | N/A | N/A |
| 0310 | 02 | 77-00 | Maint. Status | ENG 2 FADEC | S | NO (end of flight) | 0311 | 02 | 75-21-10 | HPTC VLV(POS), HMU ENG2A | Not related to the event, present since LEG06.<br>No evidence of HPT issue before birdstrike. | | No | No |
| 0313 | 05 | 77-00 | ECAM alert | ENG 1 REVERSE UNLOCKED | C | Yes | 0314 | 05 | 78-31-00 | TR LATCH, STOW SW ENG1A | Consistent with primary latch detected opened by EEC | REV1 UNLOCK=1 @03:13:47 UTC | No | No |
| | | | | | | | 0314 | 05 | 78-31-00 | TR LATCH, STOW SW ENG1A | *Same as previous failure message* | | No | No |
| 0313 | 05 | 77-00 | ECAM alert | ENG 1 PROBES FAULT | C | NO *(*)* | 0314 | 05 | 73-21-40 | T12 SNSR, J9, ECU ENG1A | Consistent with T12 damaged during birdstrike and invalid | | No | No |
| | | | | | | | 0314 | 05 | 73-21-40 | T12 SNSR, J9, ECU ENG1A | *Same as previous failure message* | | No | No |
| 0314 | 05 | 77-00 | ECAM alert | AUTO FLT AP OFF | W | Yes | | | | *No FM as pilot action* | Involuntary disconnection through rudder pedals, no failure | APOFFW=1 @03:14:06 UTC | N/A | N/A |
| 0314 | 05 | 77-00 | ECAM alert | ENG 1 STALL | C | NO *(*)* | | | | *No FM for this alert* | Consistent with recorded N1/thrust loss. First detection | N1A1 loss @03:13:47 UTC | No | No |
| 0314 | 05 | 77-00 | ECAM alert | ENG 1 EGT OVER LIMIT | C | Yes | | | | *No FM for this alert* | Consistent with EGT1 > 950°C recorded in DFDR (first occurrence) | EGT1>950°C @03:14:17 UTC | Yes [1] | No |
| 0314 | 05 | 77-00 | ECAM alert | ENG 1 STALL | C | NO *(*)* | | | | *No FM for this alert* | Consistent with recorded N1/thrust loss. Second detection | N1A1 loss @03:13:47 UTC | No | No |
| 0314 | 05 | 77-00 | ECAM alert | ENG 1 EGT OVER LIMIT | C | Yes | | | | *No FM for this alert* | Consistent with EGT1 > 950°C recorded in DFDR (second occurrence) | EGT1>950°C @03:14:41 UTC | Yes [2] | No |

S=Status
C=Caution
W=Warning
(*) inhibited in FP05

*Notes :*
*[1] ENGINE GAS PATH ADV REPORT 15AUG - 031419 - RPT06.txt*
*[2] ENGINE GAS PATH ADV REPORT 15AUG - 031442 - RPT06.txt*

*Figure 69. Index of messages*

### 1.16.6. Results of the Analysis of Crew Psychological Tests[23]

This section presents the results of the analysis of crew psychological testing data. The analysis was carried out by a psychologist with 25 years of experience working in the field of psychiatric diagnostics (mainly clinical) at an expert level; a professorship; supervisory experience; and experience with personality evaluations in a legal context.

**The Captain**

The following materials were provided to the investigation:

- Psychological observation report for the position of "pilot-engineer," 05/07/2010, without SMPA (Standardized Multifactor Personality Analysis)[24] data.
- Psychological observation report for regular medical certification, 26/07/2012.
- Psychological observation report "for psychological symptoms," 23/01/2013.
- Psychological observation report for acquisition of a new aircraft type rating, 25/09/2013, without SMPA data.
- Psychological observation report for upgrade to Captain, 06/04/2018.

The cognitive functioning test reports from 2010, 2012, 2013 and 2018 show a satisfactory (intermediate to high) level of development and functioning.

The data from the SMPA personality tests (except the 2012 profile, in which the fourth scale was over 70T points) corresponded to a "normative" personality, as their scales fell within the range from 40T-60T.

The fourth scale from the SMPA test, concerning impulsivity, showed an excitable tendency accentuated by increased impulsiveness, non-conformity, and difficulties with self-control. The 2012 profile was judged as non-normative, and as a result the pilot was placed under six months of psychological observation "for psychological symptoms."

The configuration of the trustworthiness scales K, F, and L in all available profiles reflects the presence of an attitude toward the observation procedure and significant discomfort under testing, and the difference between the raw points F and K (-19, -20, -17) indicates a closed-off attitude and lack of candidness, as a result of which the profile cannot be considered trustworthy.

Furthermore, the 2018 profile shows a low distribution plateau (all scales on the level of 40T), which also points to a lack of candidness under testing. Similar profiles reflect the personal and emotional immaturity of the subject, which is associated with problems related to questions of authority/subservience. In such cases, evaluation of the profile requires careful quality analysis (and not only along the formal principles of yes/no, satisfied/unsatisfied) or additional data acquired via non-verbal methods.

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[23] The Commission is providing detailed examination data because, in the Commission's opinion, the psychological personality profiles of the crewmembers, including their manner of behavior (reaction) in abnormal (stressful) situations, substantially affected their actions during an unusual situation in flight.

[24] *Translator's note: the SMPA was the Soviet analog of what is known in the West as the Minnesota Multiphasic Personality Inventory (MMPI).*

***Note:*** *A sufficiently high level of intellect allows a subject to successfully manipulate the results of verbal testing in order to avoid answers that could place them in an undesired category. For this reason, the fact that a personality profile falls within the normal range is not in and of itself a sufficient basis on which to determine the subject's level of adaptation/maladaptation.*

Despite his adaptive test-taking behavior, closed-off attitude, and lack of candidness, using the three profiles from various years it is possible, through the identification of repeating patterns and with the help of a qualitative analysis, to make some assumptions about the Captain's personality characteristics and behavioral peculiarities in abnormal situations.

The Captain's 2012 personality profile was dominated by the 4th and 1st scales, which in the presence of a closely spaced 3rd scale indicates a combined reactionary and excitable personality type. This type combines impulsiveness, activity, tendency toward domination, rivalry, and difficulty adhering to societal norms with a drive toward increased self-control. The collision of the reactionary defense mechanisms and displacement typical of the 4th scale with the over-controlling tendencies of the 1st scale leads to a somatization of excitement and anxiety, displacement, and denial of aggression (related to the suppressed 6th scale in all available profiles); and the transformation of these traits into their latent equivalents. In everyday life, this grants the ability to effectively manage anger, impulsiveness, and increased excitability, but in high-stress situations these contradictory traits can lead to freezing, delayed reactions, and basic automatic behavior. In particularly critical situations, behaviors can become disorganized, resulting in a flurry of chaotic actions.

The Captain's 2013 personality profile (which was conducted to follow up on the unsatisfactory result in 2012)[25] differed minimally from the previous profile in terms of qualitative peculiarities, although it was categorized as normative due to a reduction in the 4th scale indicators. The controlling characteristics increased not because of an increase in thoughtfulness or self-awareness, but because of an increase in defense mechanisms and somatization of anxiety and excitement (growth in the 3rd scale).

In the opinion of a psychologist, the Captain's 2018 personality profile cannot be considered trustworthy due to the configuration of the correction scales, the reduction and flattening of the profile, and the pronounced decrease in the 4th and 6th scales.

***Note:*** *In previous profiles, the 4th scale was the most prominent, so such a sharp change cannot be considered trustworthy without a clinical basis, and the cognitive tests and medical commission data did not support the existence of a clinical basis; furthermore, the reduction in the 6th scale to the 40T range in a healthy young male reflects either denial and displacement of aggression, or an attempt to cover it up.*

The psychologist drew the following conclusions:

- The Captain's personality is characterized by a combined type consisting of reactionary behavior and excitability, impulsiveness, tendency toward domination, and difficulty with authority and adhering to societal norms, with denial and displacement of negative

[25] Both examinations (2012 and 2013) were conducted while the Captain was studying at the Saint Petersburg State University High Technical School for Civil Aviation.

information being the primary defense mechanisms. Control over his physiological reactions helps him manage these characteristics, through the somatization of impulses and negative emotions (excitement is directed not toward external objects and actions, but toward the self). In everyday life this helps him effectively control his affect and behavior. In highly stressful situations such a mechanism can lead to disorganized behavior.

- The peculiarities of the Captain's personality could have a significant influence on his behavior in abnormal situations, and could induce latent reactions within which only automatic behaviors and actions are possible. His behavior under such situations could be disorganized, chaotic, inconsistent, and random.

**The First Officer**[26]

The following materials were provided to the investigation:

- Psychological observation data for training for the position of "pilot-engineer" at Krasnokutsk Flight School No. 23, 18/07/2014.
- Psychological observation data for acquisition of a new aircraft type rating, 05/06/2018.
- Psychological observation data for treatment of hypertension-induced neurocirculatory dystonia, 20/05/2019.

The cognitive functioning test reports from 2014, 2018, and 2019 show a satisfactory (intermediate to high) level of development and functioning.

The SMPA personality test data allow all three personality profiles to be considered normative, since their scales fall within the 30T-60T range. The configuration of the trustworthiness scales K, F, and L in all the profiles reflects significant discomfort under testing, with compensatory behavior, and a difference between the raw points on scales F and K (-19, -11, -17) suggests a negative relationship to the test, a closed-off attitude, and a lack of candidness, which means that the 2014 and 2019 profiles should be considered untrustworthy. In such cases, evaluation of the profile requires careful quality analysis or the addition of data acquired by non-verbal methods. Furthermore, such configurations reflect the personal and emotional immaturity of the subject, associated with difficulties respecting authority.

By conducting a qualitative analysis and identifying trends in the three available profiles, it is possible to draw certain conclusions about the personality of the First Officer.

The First Officer's 2014 personality profile characterizes him as emotionally immature, with exaggerated and unstable self-analysis, a competitive nature, a tendency toward domination, difficulties with authority and adherence to societal norms, impulsiveness, poorly thought-out actions, and a tendency to reject and displace anxiety and negative information about reality and about himself ($9^{th}$, $4^{th}$, and $2^{nd}$ scales leading, high K correction scale). In high-stress situations, he is likely to experience increased excitability, with unconscious violations in purpose and sequence of actions. In similar situations the sthenic scale (elevated $4^{th}$ and $9^{th}$ scales) will not be conducive to stress tolerance, but it will intensify excitability and disorganization.

[26] Translator's note: This section contains a footnote which is not attached to a reference indicator anywhere in the next. The footnote states: "The initial professional psychological examination report card mentioned an educational institution at which, according to the pilot, he aspired to study. In reality the First Officer studied at the Saint Petersburg State University Higher Technical School for Civil Aviation in Buguruslan."

Despite a change in its configuration (a significant decrease in the 2nd, 7th, and 8th scales, which only intensified the pattern described earlier due to decreased social sensitivity and versatility), the First Officer's 2018 personality profile generally retained the previously described behavioral and personality patterns. Additionally, there was a decrease in communicative difficulties (a combination of the 2nd and 8th scales at the start of the first profile) and both profiles showed an excessive penchant for risk, in combination with a disregard for and underestimation of danger (a significant increase in the 9th and 4th scales).

The First Officer's 2019 personality profile for the most part retained the same personality and behavioral patterns, and was characterized by an increase in emotional instability and mood swings (a significant increase in the 8th, 3rd, and 7th scales) bearing more similarity to his earliest profile from 2014, which signifies a lack of the growth dynamic that normally suggests softening and smoothing over of excitable and impulsive characteristics. Consequently, his various maladaptations in high-stress situations remained the same.

The psychologist drew the following conclusions:

- The First Officer's personality is characterized first and foremost by the sthenic register, excitability, impulsiveness, tendency toward domination, a competitive nature, emotional immaturity, exaggerated and unstable self-analysis, and difficulties with authority and adherence to social norms, with denial and displacement of negative information as the primary defense mechanism. In high stress situations, increases in the excitability of emotional and latent instabilities lead to violations in purpose and sequence of actions to the point of disorganization.
- The peculiarities of the First Officer's personality data may have a significant influence on his behavior in abnormal situations due to their effect on his organization and consistency.

### 1.17. Relevant Organizational and Management Information

The aircraft operator was Ural Airlines (Air Operator Certificate No. 18, issued by Rosaviatsiia on 25/06/2019). According to its operating certificate, Ural Airlines has the right to carry out commercial passenger and cargo flights using the A321-211 VQ-BOZ. Its mailing address is 620025 Utrennyy Pereulok, Building 1G, Yekaterinburg, Sverdlovsk Oblast', Russia.

Ramenskoe Airport is operated by the M. M. Gromov Flight Institute, which holds civil Aerodrome Operator Certificate No. FAVT.OA-44, issued by the Rosaviatsiia Airport Management Department on 05/12/2016. Its mailing address is 140180 Ulitsa Garnaeva, Building 2A, Zhukovskiy, Moscow Oblast', Russia.

Zhukovskiy International Airport[27] is an international airport of federal significance in Moscow Oblast', belonging to RAMPORT AERO (an international holding company specializing in the construction, development, and operation of airport complexes). RAMPORT AERO holds a certificate of compliance with the Federal Aviation Regulations, No. FAVT.AB.176, issued by the Rosaviatsiia Transportation Safety Department on 02/10/2018. Its mailing address is 140180 Ulitsa Narkomvod, Building 23, Zhukovskiy, Moscow Oblast', Russia.

[27] Translator's note: "Ramenskoe Airport" appears to refer to the entire facility, which includes various types of aviation, while "Zhukovsky International Airport" refers specifically to the part which is an international airport.

Oversight of the activities of entities involved in civil aviation is carried out by the Central Federal Region State Aviation and Transportation Safety Oversight Department of the Federal Transportation Oversight Service. Its mailing address is 140002 Oktiabrskiy Prospekt, Building 15, Liubertsy, Moscow Oblast', Russia.

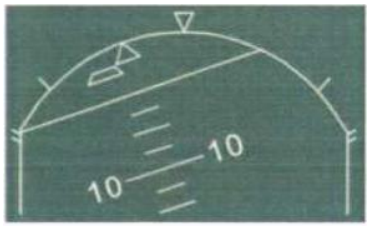
## 1.18. Additional information

### 1.18.1. Indications of Sideslip Angle and Commanded (Target) Sideslip Angle (BETA TARGET)[28]

*FCOM. DSC-31-40. AIRCRAFT SYSTEMS. INDICATING/RECORDING SYSTEMS. INDICATIONS ON PFD*[29]

*(6) Sideslip Index (yellow)*

*This trapezoidal index moves beneath the roll index. On ground, it represents the lateral acceleration of the aircraft. In flight, it shows sideslip (as computed by the FAC). One centimeter of displacement indicates 0.2 g. The sideslip index is against its stop at 0.3 g.*




*In case of engine failure at takeoff or go around, the sideslip index changes from yellow to blue.*

*Note: The sideslip angle is blue, if:*

- *CONF 1, 2, or 3 is selected, and*
- *Any ENG N1 > 80% or one Thrust Lever > MCT (≥FLX if FLX or DERATED TO), and*
- *The difference between the ENG N1's exceeds 35%.*

*In this case, the sideslip index is called the ß target.*

*When this index is centered with the roll index, the sideslip equals the sideslip target for optimum aircraft performance.*

*FCOM. AIRCRAFT SYSTEMS. FLIGHT CONTROLS. FLIGHT CONTROL SYSTEM – NORMAL LAW*

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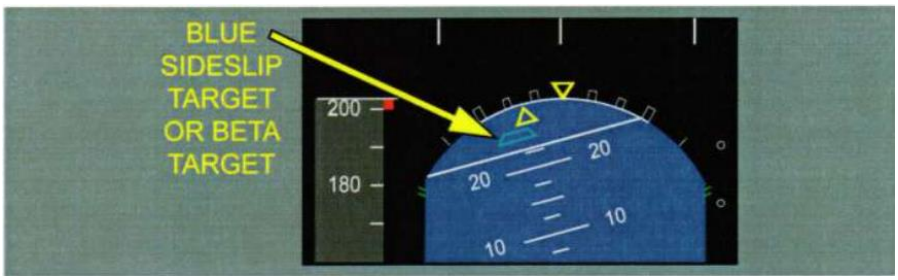
[28] Henceforth, the terms "beta target," "BETA TARGET," and "ß target" are used interchangeably.

[29] Translator's note: Italicized excerpts from aircraft documentation were rendered in English in the original report and have not been altered. This holds true throughout the remainder of the report when aircraft documentation is quoted.

*SIDESLIP TARGET*

*If one engine fails, the FAC modifies the sideslip indication slightly to show the pilot how much rudder to use to get the bests climb performance (ailerons to neutral and spoilers retracted). In the case of an engine failure at takeoff, or at go-around, the sideslip index on the PFD changes from yellow to blue (to provide the conditions for the blue display of the sideslip target, refer to DSC-31-40 Attitude Data).*




*In flight, the lateral normal law commands some rudder surface deflection to minimize the sideslip.*

*The pilot's response is normal and instinctive: zero the slip indication by applying the right amount of rudder to get the best climb performance.*

**1.18.2. FCTM Provisions upon Recognition of Engine Failure**

FCTM A321. ABNORMAL AND EMERGENCY PROCEDURES

*ENGINE FAILURE – GENERAL. PR-AEP-ENG, P 12/26*

*An engine flameout can be due to many reasons, for example:*

- *Fuel starvation*
- *Encounter with volcanic ash, sand, or dust clouds*
- *Heavy rain, hail, or icing*
- *Bird strike*
- *Engine stall*
- *Engine control system malfunction*

*An engine flameout may trigger an ECAM alert.*

*The flight crew can detect an engine flameout without damage by a rapid decrease of EPR/N1, N2, N3*,[30] EGT, and FF.*

*The flight crew can suspect engine damage, if the flight crew observes two or more of the following symptoms:*

- *Rapid increase of the EGT above the red line*

[30] The asterisk means that this equipment is optional.

- *Important mismatch of the rotor speeds, or absence of rotation*
- *Significant increase of aircraft vibrations, or buffeting, or both vibrations and buffeting*
- *Hydraulic system loss*
- *Repeated, or not controllable engine stalls.*

### 1.18.3. FCTM Provisions for Engine Failure After $V_1$

FCTM A321. ABNORMAL AND EMERGENCY PROCEDURES

*ENGINE FAILURE AFTER V1. PR-AEP-ENG,*

*AIRCRAFT HANDLING*

*If an engine fails after V1 the takeoff must be continued. The essential and primary tasks are linked to aircraft handling. The aircraft must be stabilized at the correct pitch and airspeed, and established on the correct track prior to the initiation of the ECAM procedure.*

*ON THE GROUND*

*Rudder is used conventionally to maintain the aircraft on the runway centerline.*

*At $V_R$, rotate the aircraft using a continuous pitch rate towards an initial pitch attitude of 12.5˚. The combination of high FLEX temperature and low $V_R$ speeds requires precise handling during the rotation and liftoff. The 12.5˚ pitch target will ensure the aircraft becomes airborne.*

*WHEN SAFELY AIRBORNE*

*The SRS orders should then be followed which may demand a lower pitch attitude to acquire or maintain $V_2$.*

*With a positive rate of climb and when the radio height has increased, the PM will call "positive climb."*

*This will suggest to the PF for landing gear retraction.*

*Shortly after liftoff, the lateral normal law commands some rudder surface deflection to minimize the sideslip (there is no feedback of this command to the pedals). Thus, the lateral behavior of the aircraft is safe and the pilot should not be in a hurry to react on the rudder pedals and to chase the beta target.*

*The blue beta target will replace the normal sideslip indication on the PFD. Since the lateral normal law does not command the full needed rudder surface deflection, the pilot will have to adjust conventionally the rudder pedals to center the beta target.*

*When the beta target is centered, total drag is minimized even though there is a small amount of sideslip. The calculation of the beta target is a compromise between drag produced by deflection of the control surfaces and airframe drag produced by a slight sideslip. Centering the beta target produces less total drag than centering a conventional ball, as rudder deflection, aileron deflection, spoiler deployment and aircraft body angle are all taken into account.*

*The crew will keep in mind that the yaw damper reacts to a detected side slip. This means that, with hands off the stick and no rudder input, the aircraft will bank at about 5˚ maximum*

*and then will remain stabilized. Thus, laterally, the aircraft is a stable platform and no rush is required to laterally trim the aircraft. Control heading conventionally with bank, keeping the beta target at zero with the rudder. Accelerate if the beta target cannot be zeroed with full rudder. Trim the rudder conventionally.*

*The use of autopilot is STRONGLY recommended. Following an engine failure, the rudder should be trimmed out prior to autopilot engagement.*

*Once AP is engaged, the rudder trim is managed through the AP and, hence, manual rudder trim command, including reset, is inhibited.*

*THRUST CONSIDERATION*

*Consider the use of TOGA thrust, keeping in mind the following:*

*For a FLEX takeoff, selecting the operating engine to TOGA provides additional performance margin but is not a requirement of the reduced thrust takeoff configuration. The application of TOGA will very quickly supply a large thrust increase but this comes with a significant increase in yawing moment and an increased pitch rate. The selection of TOGA restores thrust margins but it may be at the expense of increased workload in aircraft handling.*

*For a derated takeoff, the flight crew cannot apply asymmetric TOGA thrust if the speed is below F,[31] due to VMCA[32] considerations.*

| | |
|---|---|
| ***WARNING*** | *If the takeoff is performed at derated takeoff thrust, selecting TOGA at a speed below F can lead to loss of control of the aircraft.* |

*Takeoff thrust is limited to 10 minutes.*

*PROCEDURE*

*INITIATION OF THE PROCEDURE*

*The PM will closely monitor the aircraft's flight path. He will cancel any Master Warning/Caution and read the ECAM title displayed on the top line of the E/WD.*

*Procedures are initiated on PF command.*

*No action is taken (apart from cancelling audio warnings through the MASTER WARNING light) until:*

*The appropriate flight path is established and,*

*The aircraft is at least 400 ft above the runway.*

*A height of 400 ft is recommended because it is a good compromise between the necessary time for stabilization and the excessive delay in procedure initiation.*

*Priority must be given to the control of aircraft trajectory. Once the PF has stabilized the flight path, the PM confirms the failure and the PF orders ECAM actions.*

*The flight crew should delay the acceleration for securing the engine. An engine is considered secure when the ECAM actions of the procedures are performed until:*

*ENG MASTER for an engine failure without damage OFF*

*AGENT 1 DISCH for an engine failure with damage.*

[31] Minimum flap retraction speed.

[32] Minimum controllable speed with one engine inoperative.

*Fire extinguished or AGENT 2 DISCH" for an engine fire.*

***Note:*** *If the decision has been taken to delay the acceleration, the flight crew must not exceed the engine out maximum acceleration altitude. (The engine out maximum acceleration altitude corresponds to the maximum altitude that can be achieved with one engine out and the other engine(s) operating at takeoff thrust for a maximum of 10 min.)*

*ACCELERATION SEGMENT*

*At the engine-out acceleration altitude, push ALT pb * or push the V/S knob to level off the aircraft to allow the speed to increase. If the aircraft is being flown manually, the PF should remember that, as airspeed increases, the rudder input needed to keep the beta target centered will reduce. Retract the flaps as normal. When the flap lever is at zero, the beta target reverts to the normal sideslip indication.*

*FINAL TAKEOFF SEGMENT*

*As the speed trend arrow reaches Green Dot speed, pull for OPEN CLIMB, set THR MCT when the LVR MCT message flashes on the FMA (triggered as the speed index reaches the green dot) and resume climb using MCT. If the thrust lever are already in the FLX/MCT detent, move lever to CL and then back to MCT.*

*When an engine failure occurs after takeoff, noise abatement procedures are no longer a requirement. Additionally, the acceleration altitude provides a compromise between obstacle clearance and engine thrust limiting time. It allows the aircraft to be configured to Flap 0 and green dot speed, which provides the best climb gradient.*

*Once established on the final takeoff flight path, continue the ECAM (consider OEB, if applicable). When the STATUS is displayed, the AFTER TAKEOFF/CLIMB checklist should be completed and both the computer reset and engine relight (if no damage) considered. STATUS should then be reviewed.*

*ENGINE FAILURE DURING INITIAL CLIMB*

*This procedure is similar to the "Engine Failure after $V_1$" procedure.*

### 1.18.4. QRH Procedures for Engine Stall

*ABNORMAL AND EMERGENCY PROCEDURES 19.07A*

*ENG 1(2) STALL*

*…*
*In flight:*
*THR LEVER (affected engine)…….IDLE*
*ENG PARAMETERS (affected engine)…….CHECK*
*–If abnormal ENG parameters:*
*ENG MASTER (affected engine)…….OFF*

*ENG 1(2) SHUT DOWN*
*–If normal ENG parameters:*
*ENG ANTI-ICE (affected engine)……..ON*
*WING ANTI-ICE……ON*
*THR LEVER (affected engine)……..SLOWLY MOVE FORWARD*
*–If stall occurs:*
*THR LEVER (affected engine)…….MOVE BACKWARD*
*Reduce thrust and operate below the thrust threshold where stall recurs.*
*–If stall does not recur:*
*CONTINUE NORMAL ENGINE OPERATION*
*ABNORMAL AND EMERGENCY PROCEDURES 19.09A*
*HIGH ENGINE VIBRATION*
*ENG PARAMETERS……CHECK*

### 1.18.5. Critical Angle of Attack and Stall Protection System

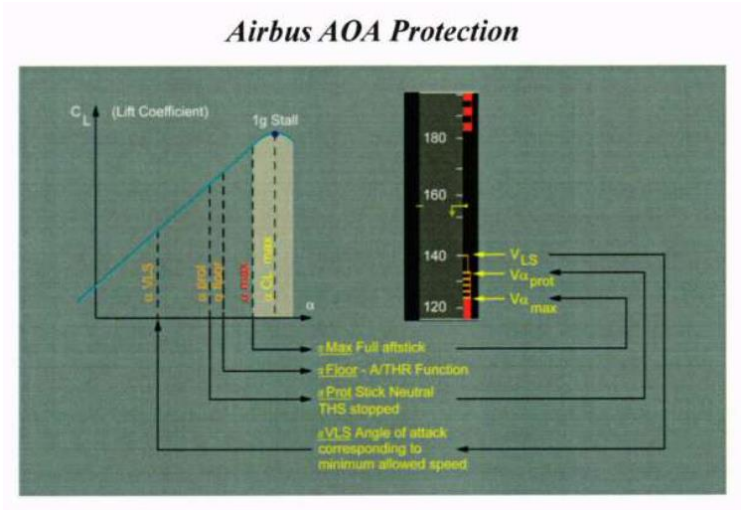
*FCOM. DSC-27-20-10-20. AIRCRAFT SYSTEMS. FLIGHT CONTROLS. FLIGHT CONTROL SYSTEM – NORMAL LAW*

*HIGH ANGLE-OF-ATTACK PROTECTION*

*In the normal law, the aircraft is protected against stall, in dynamic maneuvers or gusts. When the current angle-of-attack becomes greater than αPROT, the high angle of attack (AOA) protection activates.*

*Without pilot input the F/CTL computers will maintain the AOA equal to αPROT. The AOA can be further increased by the pilot input, up to a maximum value equal to αMAX. When the High AOA protection is activated, the normal law demand is modified and the side stick input is an angle-of-attack demand, instead of a load factor demand.*

*The PF must not deliberately fly the aircraft in the High AOA, except for brief periods, when maximum maneuvering speed is required.*



*Vα PROT, Vα floor, Vα MAX are mainly computer based on the AOA, and therefore they vary with configuration, weight and load factor.*

*Refer to DSC-22_10-50-20 Characteristic Speeds for more information.*

*The angle-of-attack will not exceed αMAX, even if the pilot gently pulls the sidestick all the way back. The pilot can hold full back stick, if it is needed, and the aircraft stabilizes at an angle-of-attack close to but less than the 1 g stall. When flying at αMAX, the PF can make gentle turns, if necessary. If the pilot release the sidestick, the angle-of-attack returns to αPROT and stays there. As the aircraft enters protection at the amber and black strip (αPROT), the system inhibits further nose-up trim beyond the point already reached. The nose-down trim remains available, if the pilot pushes the stick forward.*

*Note: At takeoff, the αPROT is equal to the αMAX for 5 s.*

*This High AOA protection has priority over all other protections.*

*The aircraft can also enter αPROT at a high flight level, where it protects the aircraft from the buffet boundary. As at a low speed or low flight level, if the sidestick is merely released to neutral, the aircraft maintains the alpha for αPROT. This value of alpha is not the same as the value used at the low speed. Alpha for αPROT is reduced as a function of Mach, so that a typical cruise value is about 3.5˚ for the A318 and A321 aircraft, or 4.5˚ for the A319 and A320 aircraft. Therefore the aircraft may climb with the sidestick free, when leaving a turn after entering αPROT.*

*If the pilot flies into αPROT, he should leave it as soon as other considerations allow, by easing forward on the sidestick to reduce alpha below the value of αPROT, while simultaneously adding power (if the αfloor has not yet been activated, or cancelled).*

*To deactivate the angle of attack protection, the pilot must push the sidestick:*

- Greater than 8˚ forward, or,
- Greater than 0.5˚ for at least 0.5 s when α < αMAX.

*Between the αPROT and αMAX, αfloor protection may automatically set the go-around thrust. The αfloor will usually be triggered just after entering αPROT, and the go-around thrust will automatically be applied. Therefore, if the side stick is held aft, either inadvertently or deliberately, the aircraft will start to climb at a relatively constant low airspeed. To recover a normal flight condition, the αPROT should be exited by easing forward on the sidestick, as described above, and the αfloor should be cancelled by using the disconnect pushbutton on either thrust lever as soon as a safe speed is regained. Refer to DSC-22_40-30 Alpha-Floor Protection for more information.*

### 1.18.6. Company FOM provisions for evaluating takeoff procedures during recurrent simulator training

According to the information provided by the airline, evaluation of trainee pilots in the simulator is conducted by instructor pilots based on the document entitled “A319/320/321 Flight Crew Simulator Training Procedures” (approved by the Ural Airlines director of flights on 14/05/2018), in which chapter 7, entitled “Trainee Pilot Session Proficiency Criteria and Paperwork,” states, in point 7.2., that “upon evaluation of piloting quality, the instructor is obliged to follow the established grading system, described in Appendix 1 to the Flight Crew Training Program.”

***Note:*** *A319/320/321 Flight Crew Simulator Training Procedures.*

*Appendix 1. Evaluation Standards for Piloting and Navigation Techniques*

| *Check content* | *Grades for determining the level of flight crew professional readiness* | | |
|---|---|---|---|
| | *"5"* | *"4"* | *"3"* |
| | *2. Flight conduct* | | |
| *2.2 Takeoff:* | | | |
| *a) Directional control during takeoff* | *On runway axis* | *Deviation of up to 2 m from the runway axis* | *Deviation of up to 5 m* |
| *b) Rotation speed (knots)* | *+5 above calculated* | *+10 above calculated* | *+15 above calculated* |
| *c) Liftoff speed (knots)* | *calculated* | *+5 above calculated* | *+10 above calculated* |
| *2.3 Positive climb* | | | |
| *a) Speed (knots)* | *±5 off normal* | *±10 off normal* | *±15 off normal* |

The actual deviation is evaluated subjectively (qualitatively) by the instructor in the "online" regime, without using objective means of data recording, which are not available in the simulator.

### 1.18.7. Pre-takeoff Runway Inspection

There is no photo or video monitoring of the condition of the airfield, except at the RAMPORT AERO ramp.

According to the statements provided by the airport director, he conducted a runway inspection between 02:30 and 02:50, after which he reported the results of the inspection by telephone to the director of operations.

***Note:*** *1. From the statements of the airport director on 18/08/2019:*

*"At 05:30 (Moscow time), prior to the first flight of the day and knowing the flight schedule, I left to inspect the runway in a personal vehicle equipped with a flashing beacon and a portable radio tuned to the aerodrome frequency, so that the service vehicle wouldn't run empty (its battery was low). From taxiway B7 I requested permission to enter the runway.*[33] *The connection was unstable. I did not receive confirmation. I decided to inspect the runway along with my next report to the director of operations, since the schedule said it would be more than 30 minutes until the next departure. At 05:50, using telephone 71-80 (control tower 2), I reported the results of the runway inspection to the director of operations. Runway 12/30 was wet with puddles up to 2 mm deep, friction coefficients = 05/05/05, R12 21/02/50, R30 21/02/50. I also reported the absence of any extraneous objects or birds on the runway. I recorded a note about the runway inspection and its results in the runway inspection log at 6:00."*

*2. From the statements of the director of operations on 18/08/2019:*

[33] This request was not registered on the ATC recording.

*"…30 minutes before launch at 2:30 UTC, the airport director conducted an inspection of runway 12/30, and at 2:55 UTC he reported by telephone that there were no extraneous objects or birds on the runway…"*

The order in which these tasks were to be carried out (including the runway inspection) was defined by the document entitled "Technological Coordination Between the Aerodrome Technical Service, Transport Service, and Other Ground-Based Flight Support Services at Ramenskoe Airport," approved by the Director General of the M. M. Gromov Flight Institute and coordinated with the Director General of RAMPORT AERO.

***Note:*** *Technological Coordination Between the Aerodrome Technical Service, Transport Service, and Other Ground-Based Flight Support Services at Ramenskoe Airport:*
*"1. General requirements (personnel responsible for evaluating the readiness of the airport for flights and for allowing and prohibiting the arrival and departure of aircraft).*
*…*
*1.3. Tasks within the boundaries of the flight movement area (except for the RAMPORT AERO ramp—henceforth, the controlled zone) to prepare it for flights are to be conducted only with the permission of the airport director of operations (DO) and under the supervision of a responsible member of the aerodrome technical service, overseeing the readiness of the airport and the conduct of the work.*
*…*
*1.5. Entry into the flight movement area and taxiways by specialized vehicles and devices for the servicing and preparation of airport surfaces and landing aids, as well as vehicles associated with the duties of service personnel, is permitted only with permission of the DO.*
*1.6. Airport vehicles used for conducting work on the airfield must be equipped with working means of intra-airport radio communication with the DO, flashing (pulsating) beacons, side lights, full-strength towing devices, and cables.*
*1.7. Personnel participating in aerodrome flight support activities, and organizing and controlling the conduct of work on the flight movement areas, must continuously monitor the designated frequency for intra-airport communications, and during work on the flight movement must continuously monitor radio traffic on the Startup and Tower ATC frequencies.*
*…*
*8.4. All conversations between the director of operations and the responsible Ramenskoe Airport service personnel while conducting work in the flight movement area should be carried out only by radio and must be recorded on an electronic receiver.*

The telephone that the airport director said he used to report the results of the runway inspection to the director of operations is not connected to the automatic registration system, and no recording takes place on the receiver.

### 1.18.8. Certification of Ramenskoe Airport

In accordance with the provisions of Volume 1 of the Airport Certification Rules, FAR Part 139 “Certification of Airports” (henceforth, FAR part 139 vol. 1), the MAK Airport and Equipment Certification Commission issued certificate No. 088 A-M for Ramenskoe Airport on 12/11/2015.

Certificate No. 088 A-M was held by the M. M. Gromov Flight Institute.

FAR part 139 vol. 1 listed the responsibilities of the certificate holder, to which non-compliance would give the certificating body the right to suspend or revoke the certificate.

Following the entry into force of Resolution No. 1283 of the Government of the Russian Federation on 10/12/2015, the functions and responsibilities of the airport certificating body were transferred to Rosaviatsiia.

On 25/01/2016, Russian Ministry of Transportation order No. 11 replaced the previous Russian Ministry of Transportation order No. 48 of 05/07/1994, as a result of which FAR part 139 vol. 1 ceased to be enforced on the territory of the Russian Federation.

It should be noted that under Article 8, Part 1, Paragraph 1 of the Air Codex of the Russian Federation (version No. 253-F3 of the Federal Law, 21/07/2014), airports approved to handle commercial flights involving aircraft with more than 20 passenger sears, as well as airports open for international civilian flights, must possess a certification issued by an organ empowered to do so by the Government of the Russian Federation in accordance with the Federal Aviation Regulations. At the time of the accident, the relevant regulations were absent.

Following the termination of FAR 139 vol. 1 on the territory of the Russian Federation, there was no longer any regulatory basis for establishing the responsibilities of the Ramenskoe Airport certificate holder, with which the airport’s compliance was the condition of its certificate.

The Commission has established that due to the termination of FAR 139 Vol. 1, the cessation of its enforcement on the Territory of the Russian Federation, and the transfer of the functions and responsibilities of the certificating organ to Rosaviatsiia, the MAK-issued certificate No. 088 A-M was technically no longer valid.

Furthermore, Rosaviatsiia did not issue a new certificate for Ramenskoe Airport under the provisions of Article 8, Part 1, Point 1 of the Air Codex of the Russian Federation; therefore, the requirements of this article were not met at the time of the accident.

### 1.18.9. Design of the Thrust Reverser System

The FCOM contains a description of the design of the thrust reverser system (section DSC-70-70).

In order to generate reverse thrust, each engine is equipped with four blocker doors.

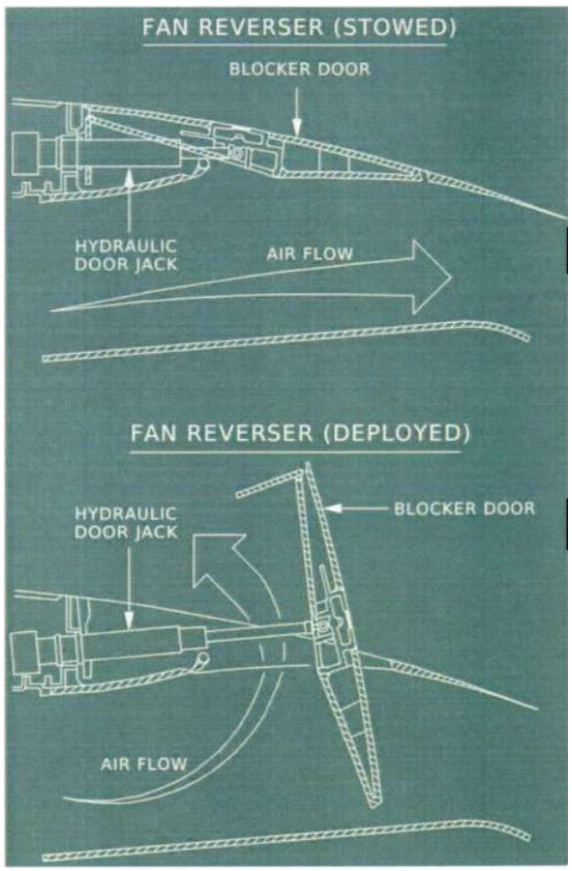


*Figure 70. Thrust reverser operation schematic*

Each blocker is hydraulically actuated.

Each thrust reverser system is controlled by the corresponding FADEC. Each FADEC channel carries out both monitoring and command functions. The left and right thrust reverser systems are independent from one another.

Each thrust reverser system consists of the following:

- Four actuators
- Four locks
- Door position sensors
- A Hydraulic Control Unit (HCU), which:
    - Provides pressure to the reverser system;
    - Controls the movement speed of the blocking doors;
    - Provides pressure directly to the hydraulic lines.
- A hydraulic cutoff valve, through which pressure is provided to the HCU.

Each reverser door moves independently (there is no synchronization between them).

The deployment time does not exceed two seconds.

In the stowed position, each blocking door is held in place by two locks: a primary lock, which is affixed to the door itself, and a secondary hydraulic lock.

When a “deploy” command is issued, the primary locks open hydraulically.

The third layer of defense is the fact that the Spoiler Elevator Computers (SECs) will only open the hydraulic cutoff valve, providing pressure to the system, if all the conditions for reverser deployment are met.

### 1.18.10. Excerpts from Flight Crew Statements

The Commission made use of interviews of the flight crewmembers, conducted by law enforcement on the day of the accident; explanatory statements presented to the Commission on 19/08/2019; and the results of interviews with the Captain (06/09/2019) and the First Officer (13/12/2019).[34]

#### Regarding the General Bird Conditions at Ramenskoe Airport

From the Captain's first interview: *"I want to be clear that flocks of birds are frequently observed at Ramenskoe Airport…."* There was no information about this question in the Captain's explanatory statement. From the Captain's second interview: *"I never encountered any officially documented information about adverse bird conditions at Ramenskoe Airport…. On this last trip, I don't remember exactly which day and which flight, at a height of 50-100 meters on takeoff I saw a bird fly past me. Previous experience has shown that this airport isn't any different from others."*

#### Regarding Bird Observations Before the Flight

From the Captain's first interview: *"Before steering the aircraft onto the runway, I saw a flock of birds, a very large number, and they flew away from the runway as we were taxiing."* From the Captain's explanatory statement: *"While turning from the main taxiway onto taxiway B7, I saw a large flock of birds (possibly seagulls, about 25-30 individuals) take off from Runway 12 (they were located about 200-300 meters from B7 along Runway 12) and fly past us to the east…. At the very start of the takeoff roll, I saw two birds about 400-500 meters ahead, which were already above the runway at a height of 5-10 meters and were located above us and to the right. I said: 'Come on bird, fly away.' The birds disappeared from view."* From the Captain's second interview: *"The first time I saw birds was when I was turning onto taxiway B7 from the main taxiway; I didn't see where they were sitting, but I did see them fly up, a flock of birds, after increasing engine power…. At the start of the takeoff roll, I saw several individual birds, 2 or 3, right of the centerline, moving away from us, and I said: 'Come on bird, fly away.'*

From the First Officer's first interview: *"The takeoff was conducted without delay at 06:10 UTC. I want to be clear that I had been seeing birds before that point… on 15/08/2019, before taxiing onto the runway, I also saw a rather large flock of birds (30-40 individuals)…. We expected the flock of birds to abandon the runway when we ran up the engines…."* From the First Officer's explanatory statement: *"The Captain and I saw a flock of birds in the takeoff area, and we decided to wait while they flew away."* From the First Officer's second interview: *"When we ran up the engines, we taxied out and saw a flock of birds. The Captain said: 'Alright, let's wait right now while this flock flies away.' We sat there and waited, and the flock flew away directly in front of us."*

[34] The dates of the crew interviews were selected taking into account their health and ability to answer the Commission's questions.

**Regarding the Bird Strike**

From the Captain's first interview: *"After takeoff, about ten seconds, a flock of birds began to cut through the space in front of the aircraft from left to right. The aircraft cut through the flock and I heard banging sounds against the aircraft fuselage; after that I heard a change in the engine working regime, and the plane started to lose speed and altitude."* From the Captain's explanatory statement: *"At $V_R$ speed, I started to rotate the airplane at the First Officer's command, and I saw a large flock of birds (25-30 individuals) located beyond the left edge of the runway, which then began to move from left to right, intersecting with our course. After several seconds I heard multiple bird impacts against the exterior of the airplane and sounds of abnormal engine operation. The aircraft continued to gain altitude."* From the Captain's second interview: *"At the start of the rotation, when the nose gear was coming up, I saw a large flock of birds fly sharply upward and from left to right. Based on the multiple impacts and sound of the engines I determined that we had struck the birds."*

From the First Officer's first interview: *"A very short time after takeoff, a rather large flock of birds cut into the airspace from left to right. The aircraft collided with the flock of birds, and I heard banging and impact sounds coming from the left side of the plane."* From the First Officer's explanatory statement: *"After liftoff I saw a flock of birds approach from left to right; after that there were several impact sounds (bangs)."* From the First Officer's second interview: *"During the takeoff, after liftoff, a flock of birds started to intrude on our course from left to right. The flock was large. I spotted the movement of the birds during the takeoff, when they began to cut into the takeoff trajectory, and I felt impacts."*

**Regarding the Behavior and Control of the Engines After the Collision**

From the Captain's first interview: *"…the No. 1 (left) engine failed, the second engine (right) started surging with an N1 close to zero. The aircraft started to descend, and I placed the No. 2 engine into the takeoff regime."* From the Captain's explanatory statement: *"The First Officer called out the decrease in N1 on the left engine…. I immediately dropped my gaze down to the ECAM display and saw ENGINE 1 – REVERSE UNLOCKED (AMBER). … I remember decreasing the operating regime of the left engine. The aircraft continued forward under sharp vibrations, and I heard loud, abrupt variations in engine operation. Then the First Officer said that the right engine was not working properly…. I noticed that the aircraft had transitioned to a descent, so I commanded TOGA power on engine No. 2 (right)."* From the Captain's second interview: *"Almost immediately an ENGINE 1 REV UNLOCKED warning appeared…. Left engine thrust decreased…. Realizing that there was insufficient thrust, I understood that something was wrong, and I commanded TOGA power from both engines, then heard banging."*

From the First Officer's first interview: *"…on the engine control display, I noticed a decrease in N1 to idle on the No. 1 engine. The Captain declared an emergency to ATC, after which I heard a bang, the sound of an impact on the No. 2 (right) engine. According to the instruments, the No. 2 engine was unstable; its operation was interrupted by surging. The Captain moved the No. 2 engine into the takeoff regime. The No. 1 engine had already failed by this point."* From the First Officer's explanatory statement: *"I then noticed a decrease in N1 to idle on the No. 1 engine on the engine control display, and I immediately informed the Captain that the engine had failed. An ENGINE 1 – REVERSE UNLOCKED message appeared on the*

*ECAM, then ENGINE 1 failure…. I asked the Captain, "ECAM actions," and I heard the Captain affirm this. We managed to complete step 1, THRUST LVR IDLE, up to CONFIRM, after which a bang was heard from the right, and information about the abnormal operation (surging) of the right engine appeared on the display. I reported this to the Captain. After this he increased power on the No. 2 engine to the TOGA regime, but thrust did not increase."* From the First Officer's second interview: *"I instinctively looked at the engine parameters, and the N1 speed on engine No. 1 had decreased to idle…. The MASTER CAUTION: 'ENG FAIL' warning came on, then I asked the Captain, 'ECAM actions?' After a short time, I started to work through the ECAM at his command. I read off 'REVERSE ONE UNLOCKED.' After this I read the notes: 'IF DAMAGE' or 'NO DAMAGE.'"*

**Regarding the Shutdown of the Engines Prior to Landing**

From the Captain's first interview: *"…at the moment of touchdown, I had shut down both the No. 2 and No. 1 engines."* From the Captain's explanatory statement: *"While the aircraft was sliding across the ground, the First Officer shut down the engines."* From the Captain's second interview: *"Before touchdown I decreased the operating regime of engine No. 1. …The First officer shut down the engines independently upon touchdown using the MASTER SWITCH. I didn't give any command to shut down the engines."*

**Regarding the Question of Raising the Gear**

The Captain did not mention the landing gear during his first interview. From the Captain's explanatory statement: *"The First Officer said to me: 'Altitude,' reminding me that the airplane was descending. After this I noticed that the rate of descent had decreased, and that the gear had not been retracted, and I immediately retracted the gear."* From the Captain's second interview: *"…the airplane descended and its speed decreased. I realized that it was impossible to do anything about it. Ahead there were only an unidentified field, which was probably damp, since there had been thunderstorms, and I decided that the gear should be retracted; I looked at the gear and saw that it was extended, so I said, 'gear,' and immediately retracted it myself. I retracted the gear when I saw that we were going to touch down, in order to improve the safety of the landing, in my view, because I didn't know what was on the field below."*

The First Officer also did not mention the landing gear during his first interview. From the First Officer's explanatory statement: *"…I said to the Captain, 'Altitude,' which was at that time around 600 ft, while vertical speed was around -500 or -600 ft/min. We discussed retracting the gear and the Captain retracted it."* From the First Officer's second interview: *"…I saw a field in front of us. We glanced at the gear and noticed that it was extended. We decided to retract it.* ***Q:*** *Who made this decision? Was this discussed somehow?* ***A:*** *The Captain decided. We did discuss it. He said: 'Should we raise the gear?' and I said 'Let's raise it.' We raised the gear before landing.* ***Q:*** *Why did you decide to raise the gear immediately before touchdown? What was your motivation?* ***A:*** *The ground was damp, with wet soil, which could have caused us to cartwheel."*

From these quotations it is apparent that the crew's accounts of events changed significantly over time. The statements made on the day of the accident are much less accurate to the actual events, but are much closer to the standard operating procedures. The Commission notes that at the time the pilots' explanatory statements were written, they most likely had

preliminary information about the contents of the flight recorders, which had become even more detailed by the time of the second interviews.

Two areas where all the accounts essentially agreed were the manner in which the birds were observed while taxiing onto the runway, and the observed left engine parameters immediately after the bird strike. The descriptions of some other events differed rather significantly and even contradicted the objective data.

### 1.18.11. Selected Provisions of the ICAO Airport Services Manual (Doc 9137), Part 3 (Issue 5, 2020), "Preventing adverse presence of birds and wild animals"

Paragraph 5.3.2.8:[35] *"Propane cannons (detonators) generate a sound similar to a gun firing. Birds will usually become accustomed to propane cannons quickly when fired throughout the day, whether at arbitrary intervals or according to a previously determined schedule, and they can cause startled birds to take off into aircraft movement areas, creating an additional risk. Therefore, to keep cannons effective as a means of deterrence, they must be used only from time to time in situations where birds are located in specific areas. Their effectiveness can be increased by periodically firing the cannon at common bird species.[36] Some systems are designed so that cannons positioned around the airport can be called into action by means of a radio signal. Such systems are preferable in comparison to systems based on arbitrary intervals and a timer."*

Paragraph 5.3.2.9: *"Propane cannons are most often used to scare away deer. However, deer, like most wildlife, quickly become accustomed to their use. Therefore, such systems are best used rarely and in special situations (once every few days), and are not recommended as an effective means to scare away birds and wild animals. Propane cannons, as a rule, are most useful as a backup system that can be activated remotely. The cannons should not be automated, because this can cause birds and wild animals to be scared away into higher risk areas, and does not assist in controlling their movement."*

Paragraph 5.3.2.10: *"Distress calls are a unique type of call made by various bird species in the presence of dangerous predators. Distress calls should not be confused with other types of calls, such as contact and anxiety calls. Bird species that travel in flocks—gulls, ravens, lapwings, and starlings—as a rule will use such calls, and, consequently, usually react to them. Distress calls should be designed for a specific species, and for mixed flocks, calls of the predominant species should be used. Equipment imitating distress calls should always be operated manually, because automation can cause birds to become accustomed to the calls, causing birds to interfere with critical airspace rather than controlling their movement. Such equipment is best used with fixed loudspeakers installed on a vehicle. Portable devices can also be used. Devices for imitating distress calls should always be used while stationary, although starlings can be scared away from a slowly moving vehicle."*

Point 5.3.2.11: *"By using a device for imitating distress calls, service personnel can replicate the sound of a bird that has been caught by a predator. Other birds of this type will attempt to identify the threat, forming a group, searching the area near the sound, and flying around it in order to determine where the potential danger is located. Throwing out artificial*

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[35] Translator's note: the italicized portions of section 1.18.11 were originally written in English, and have been translated into Russian and then back to English again. This could cause a dilution of intended meaning.

[36] Translator's note: tentative translation. Other Russian speakers were also unsure what the intent of this sentence was.

*feathers (white for gulls and black for ravens, for example) which resemble the remains of a victim of a struggle can convince the flock to depart, if necessary. Airport operators should take into account the fact that predatory mammals may approach the source of the distress call in hope of receiving food. The volume of the recording should be natural, in order to avoid attracting birds from outside the airport. It is most expedient to start the broadcast from a low volume and increase the volume until birds of that specific type begin to react."*

Point 5.3.2.12: *"After the simulated distress calls have ceased, remaining birds will seek to distance themselves from the source in the form of a flock. They will fly away from the source of possible danger in the direction from which they arrived. Birds become accustomed to distress call imitating devices rather quickly; therefore, they should be used infrequently and in combination with periodic cannon fire. While the imitation distress calls are being played, other forms of deterrence should not be used, as this can cause confused behavioral reactions from the corresponding bird species."*

### 1.18.12. Other Cases of Bird Strikes at Ramenskoe Airport

Reports from Ural Airlines crews regarding bird strikes testify to the existence of an adverse bird situation at Ramenskoe Airport during the relevant portion of the year:

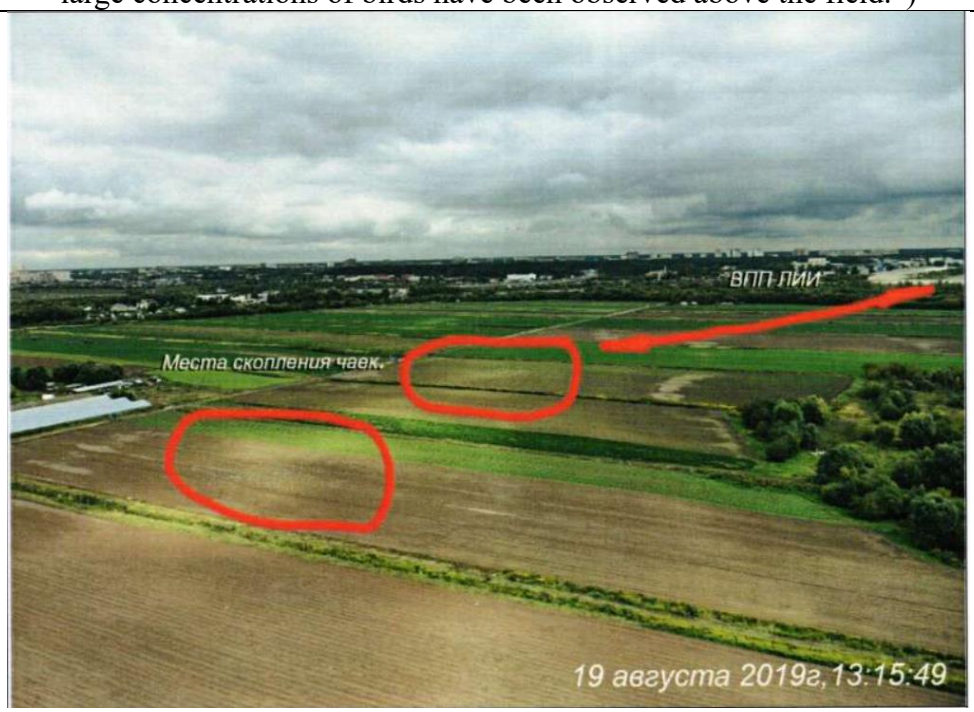
*"On 08/08/2019, at 04:55 local time, while landing at Ramenskoe Airport (flight 2446) in VQ-BOB, the aircraft collided with a flock of birds. The approach and landing were carried out on Runway 12 with the landing lights on. The initial conditions were intermittent wind 1-2 m/s, RVR 8000/4000/500 m. After passing the runway threshold at a height of 15-20 feet, a flock of birds was observed taking off from the runway and the adjacent safety areas. The plane touched down and stopped normally without any observations regarding the systems of equipment. After taxiing to the parking area and inspecting the plane, biological matter (blood) belonging to a bird was discovered on the right side of the rudder and on the interior side of the left horizontal stabilizer, along with bird feathers in engine 1, on the fairing and engine nacelle, without any visible blade damage. As a result, a bird strike report was submitted by the airline to Rosaviatsiia."*

*"On 19/08/2019, while carrying out flight 229 on A320-214 VQ-BNI, after landing on Runway 30 at Ramenskoe Airport and taxiing to the parking area, traces of a bird strike were observed. On engine No. 1 there was a patch of blood on the inlet about 10 x 10 cm, and there were traces of feathers on the fan blades. No visible damage was noted. The landing took place in darkness (22:00 local time) and was carried out normally without deviations. The Captain stated that he did not notice the moment of the bird strike. As a result, a bird strike report was submitted by the airline to Rosaviatsiia."*

### 1.18.13. Locations Attracting Birds in the Vicinity of Ramenskoe Airport

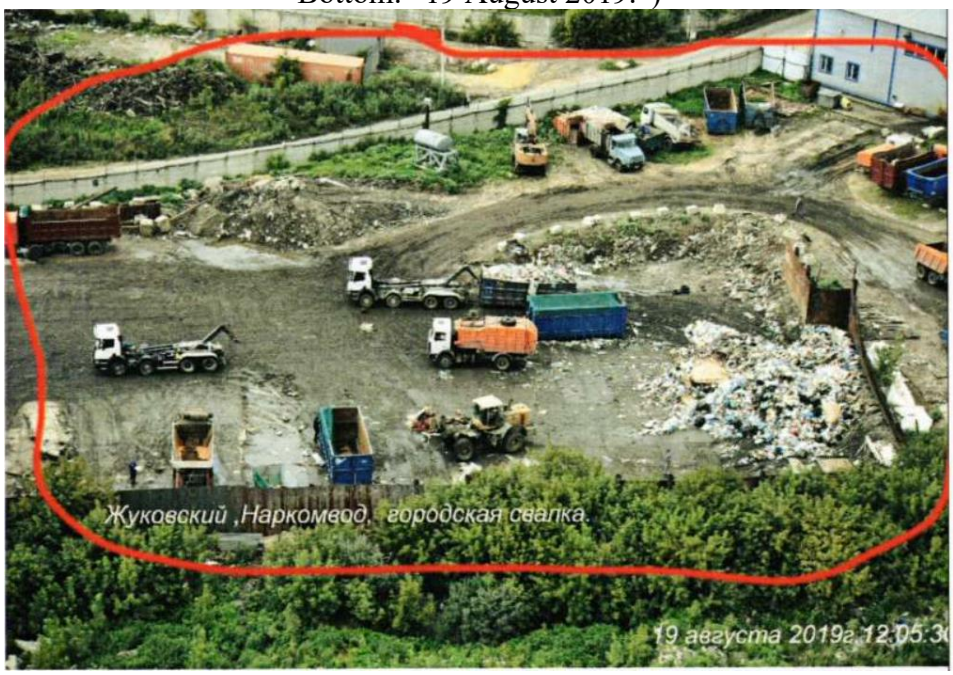
Locations in the immediate vicinity of Ramenskoe Airport which are most attractive to birds are shown in Fig. 71 and in Table 2.

*Figure 71. Locations in the vicinity of Ramenskoe Airport that are most attractive to birds*

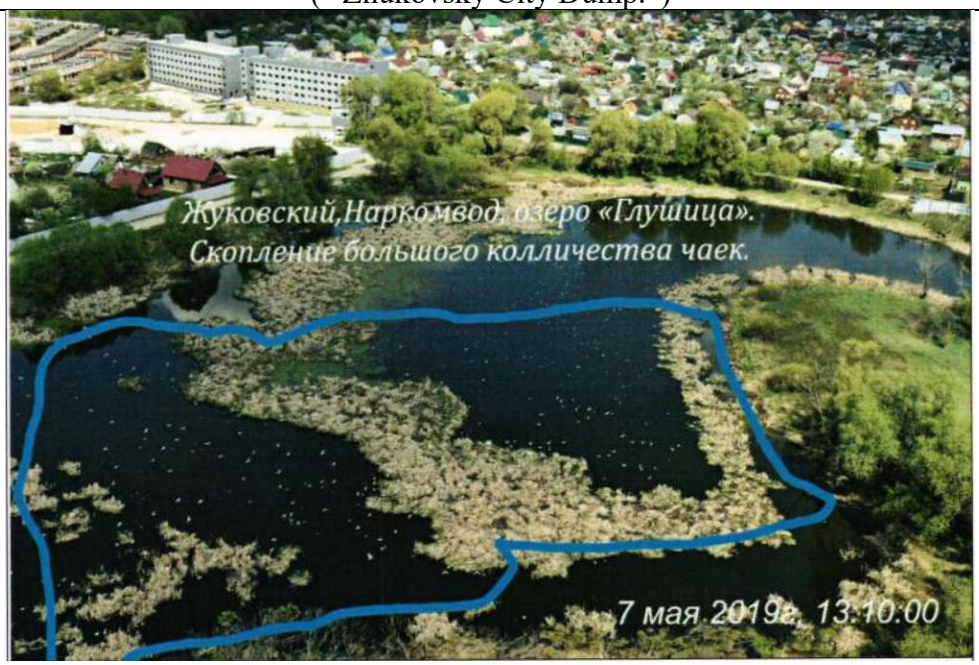
| No. / Coordinates | Photograph |
|---|---|
| 1 / 55˚33’53.19” N 38˚05’54.44” E | (“An area close to the airport runway where farm work is being conducted; large concentrations of birds have been observed above the field.”) |
| 2-3 / 55˚33’46.49” N 38˚06’04.57” E |   (Left: “Gull gathering points.” Right: “Flight Institute runway.” Bottom: “19 August 2019.”) |

| | |
|---|---|
| 4<br>/<br>55˚33’09.71” N<br>38˚06’53.39” E | <br>(Center: “Zhukovsky Narkomvod City Dump.” Bottom: “7 May 2019.”)<br> <br>(Center: “Zhukovsky Narkomvod City Dump.” Bottom: “6 August 2019.”) |

(Top: “Zhukovsky Airport.” Center: “Zhukovsky Narkomvod City Dump.” Bottom: “19 August 2019.”)




(Center: “Zhukovsky Narkomvod City Dump.” Bottom: “19 August 2019.”)

| | |
|---|---|
| | <br>( “Zhukovsky City Dump.”) |
| 5<br>/<br>55˚33’03.32” N<br>38˚07’29.43” E |  <br>(Center: “Zhukovsky, Narkomvod, Lake Glushitsa. Concentration of a large number of birds.” Bottom: “7 May 2019.”) |

| | |
|---|---|
| 6-7<br>/<br>55˚32’52.73” N<br>38˚06’57.20” E | <br>(Center: “Zhukovsky, Narkomvod, bank of the Moscow River and Lake Glushitsa landfill.” Bottom: “7 May 2019.”)<br> <br>(Top: “Zhukovsky, Narkomvod, bank of the Moscow River, landfill, and Lake Glushitsa.” Bottom: “6 August 2019.”) |

(Center: “Zhukovsky, Narkomvod, bank of the Moscow River, landfill.” Bottom: “19 August 2019.”)

(Top: “Flight Institute runway.” Center: “Location of landfill and Lake Glushitsa.” Bottom: “19 August 2019.”)

| | |
|---|---|
| | <br>("Equipment at work in the vicinity of Zhukovsky City Dump on the bank of the Moscow River.") |
| 8<br>/<br>55˚32'18.56" N<br>38˚04'52.08" E | <br>("Mikhailovskaia Sloboda Neighborhood Dump, with an arrow toward the Flight Institute airport.") |

("Mikhailovskaia Sloboda Neighborhood Dump.")

("Mikhailovskaia Sloboda Neighborhood Dump; a large concentration of gulls is visible.")

| | |
|---|---|
| 9<br>/<br>55˚33’33.48” N<br>38˚16’28.91” E | <br>(Top: “Flight Institute.” Center: “Area of former Ramenskoe City Dump.” Bottom: “6 August 2019.”) |

**1.18.14. Aviation incident involving A320-231 EY-623 on 02/02/2014 at Kulyab Airport, Republic of Tatarstan**

On 02/02/2014, an incident occurred at Kulyab Airport involving A320-231 EY-263 (Final report: https://mak-iac.org/upload/iblock/895/report_ey-623.pdf). During landing, about two seconds after touchdown, the aircraft collided with a snow bank, which led to the shutdown of both engines and the cessation of both flight recorders (CVR and FDR). The investigation commission noted that, *“The on-board crash-protected flight recorders turn off when both engines are shut down and there is no electrical power from the APU or a ground-based power source. This can lead to the complete loss of flight data in the event of a dual engine failure in flight. It would not be possible to establish the actions of the crew or their conversations during the subsequent emergency landing. This deficiency led, in part, to Commission’s inability to evaluate the actions of the crew during the latter part of the landing rollout and after the aircraft came to a stop (the Captain’s command to evacuate the passengers, etc.).”*

As a result of the investigation, the following recommendation was made to the certificatory authorities, including EASA: *“Provide for the installation of systems or devices that provide continuous, uninterrupted power to an aircraft’s flight recorders and flight data collection systems during a particular time interval following a loss of power from the main bus, in order to avoid any loss of flight recorder data upon interruption to the recorders’ power supply in the event of a failure or shutdown of the engines, or other in-flight failures.”*

On 09/05/2018, EASA provided the MAK with its final position regarding this recommendation: *“The Agency has assessed the pros and cons of a Flight Data Recorder (FDR) backup power, based on an analysis performed by the European Flight Recorders Partnership Group (EFRPG) and on subsequent discussions within an ICAO flight recorder specific working group (FLIREC-SWG), where the Agency brought this topic. Significant power is required to backup not only the FDR, but also the sensors and the acquisition of the flight parameters. In*

*addition, the benefit of a FDR backup power for investigation would probably be very limited: indeed, the available electrical power from a backup source would only permit the powering and recording of a subset of mandatory FDR parameters. Finally, this FDR power backup would only be needed for a very short duration and it would be useful in only a very small number of accidents and serious incidents. Therefore, the Agency decided not to propose a rule mandating an FDR power backup." EASA classified this recommendation as "Closed – Disagreement."*[37]

The Commission also notes that as a result of the aforementioned recommendation, EASA introduced a certification requirement for an additional power source for the CVR. This requirement will apply to aircraft with a maximum takeoff weight of more than 27 tons, whose certificates of airworthiness are issued on or after 5 September 2022.

### 1.18.15. Determination of $V_1$ and the Possibility of a Safe Rejected Takeoff Above This Speed

Modern airworthiness regulations define $V_1$ speed (decision speed) as the maximum speed during takeoff at which the pilot must take action (such as applying the brakes or reducing thrust) in order to stop the aircraft within the limits of the available rejected takeoff distance. $V_1$ speed is also the minimum speed at which the pilot may continue the takeoff following the failure of the critical engine at $V_{EF}$,[38] and still achieve the required height above the ground within the available takeoff distance. As such, $V_1$ speed is one of the most important parameters for ensuring safety during the takeoff calculations.

Extrapolating from this definition, standard operating procedures (including the Ural Airlines FOM) currently require the initiation of a rejected takeoff upon the failure of any engine or the appearance of any other failure which compromises flight safety, as long as the aircraft has not reached $V_1$, or decision speed. Conversely, continuation of the takeoff is required in the event of any failure at a speed higher than decision speed. It is therefore assumed that in the event of any failure of an aircraft system for any reason, continuing the takeoff after $V_1$ is safer than rejecting the takeoff. In keeping with this philosophy, aircraft manufacturers provide procedures for calculating rejected and continued takeoff parameters, including specific speeds ($V_1$, $V_2$, $V_R$) and the engine power settings necessary to reach them, which are usually much lower than the maximum available. These calculations make certain assumptions about the behavior of aircraft systems (for example, that in the event of a failure or malfunction of one engine on a two-engine airplane, the thrust from the other engine will remain unchanged). The manufacturers do not provide procedures for calculating the possibility of a rejected takeoff after $V_1$.

At the same time, however, the Commission notes that there are situations in which a crew may attempt to continue takeoff in an aircraft which is incapable of doing so safely (for example, due to a reduction in total engine thrust below the assumed value; an inability to achieve the required takeoff angle of attack; or a reduction in the lift coefficient due to unremoved ground icing)—that is, any actual situation outside the expected operating conditions in which the aircraft is "just unable to fly." MAK investigations have shown that in the vast majority of such situations, the crew will attempt to continue the takeoff, since the airspeed is above $V_1$, and under such circumstances the SOPs unequivocally call for the continuation of the takeoff. Attempts to continue the takeoff and lift the airplane off the ground "at any cost" therefore continue until the plane exits the runway at great speed, usually resulting in

[37] Transalator's note: The italicized passage was rendered in English in the original report and has not been altered.
[38] The proposed speed for a failure of the critical engine on takeoff.

catastrophe. Analysis of the course of events in such situations has shown that rejecting the takeoff after $V_1$, at the first sign of an inability to continue the takeoff, can significantly reduce the runway overrun speed, and, most probably, the severity of the consequences; however, crews are not psychologically prepared to reject the takeoff after $V_1$, because operational documents clearly forbid it, and they may fear punishment.

In situations such as these, the crew has the right to assert the impossibility of continuing the takeoff; however, current operational documents do not permit them to do this. The Commission believes that including the possibility of alternative actions after $V_1$ in the operational documentation would lead to reduced risk of a high speed runway overrun.

Furthermore, if a takeoff is conducted from an airport where the available rejected takeoff distance is very large (at Ramenskoe Airport, this distance is 4,600 m), then calculating the takeoff parameters with the possibility of a rejected takeoff after $V_1$ could also reduce the aforementioned risk.

***Note:*** *According to FAR part 25, the anticipated operating conditions are those conditions that are known from experience or whose existence can be reasonably foreseen in the course of the expected service life of the aircraft. These conditions include environmental conditions that affect the aircraft and operational factors affecting safety. The expected operating conditions do not include:*

*(a) Extreme conditions that can easily be avoided by adhering to operational procedures and limitations.*

*(b) Extreme conditions that occur so rarely that any attempt to ensure adherence to airworthiness regulations under such conditions would lead to a higher level of airworthiness than is necessary or well-founded.*

## 1.19. New Investigative Techniques

No new methods were used in this investigation.

## 2. Analysis

### 1.1. Description of the Flight

The forecast and actual weather conditions along the route of the flight and at the departure, destination, and alternate airports, and the airworthiness of the aircraft, had no influence on the flight.

The crew arrived at the airport approximately 1.5 hours before the flight. After completing the required pre-flight tasks (medical examination, briefing, and so on), at 02:47[39] the crew began carrying out the pre-flight checks in the cockpit. The aircraft was located in parking space 17A (see Fig. 29).

The plane had arrived from its previous flight, which was flown by a different crew, at 01:31. The Captain stated that he spoke with the previous crew. There were no observations regarding the technical condition of the aircraft.

Before the flight, the aircraft was supplied with sufficient fuel. There were no MEL deferred defects that could have influenced the course of the flight.

At 02:55:30, the cockpit voice recorder (CVR) recorded the beginning of the before takeoff briefing. During the briefing, the crew discussed, among other things, the rejected takeoff and engine failure after $V_1$ procedures. No particular matters related to birds were discussed. The Captain was the pilot flying.

At 03:00:46, the crew received the aerodrome weather information and departure clearance from the ground controller: *"Sverdlovsk-178, Ground, good morning, Runway 12 for takeoff, wind 110 degrees at 5 meters per second, visibility 7 kilometers, cloud base undefined, QNH 10-08, QFE 9-9-4, temperature 16 degrees, dewpoint 0-5, isolated bird activity. Use runway 12 for takeoff. Cleared according to the flight plan to Simferopol, on departure climb to 900 meters, contact Tower on 125.25, standby for squawk."*

At 03:04:58, at the Captain's order, the crew began the before start checklist "down to the line." The checklist was completed fully and without incident.

At 03:05:43 the crew received permission from the ground controller to push back and start their engines: "*Sverdlovsk-178, pushback on two authorized, start engines when ready."*

At 03:05:57, the flight recorder registered the release of the parking brake, after which the crew finished the before start checklist "below the line." The checklist was completed fully and without incident.

The pushback of the aircraft began at 03:06:14. The path of the aircraft across the airport (before takeoff), with radio conversations, is provided in Fig. 72.

[39] According to the schedule, flight SZhR178 had a planned departure time of 03:10.

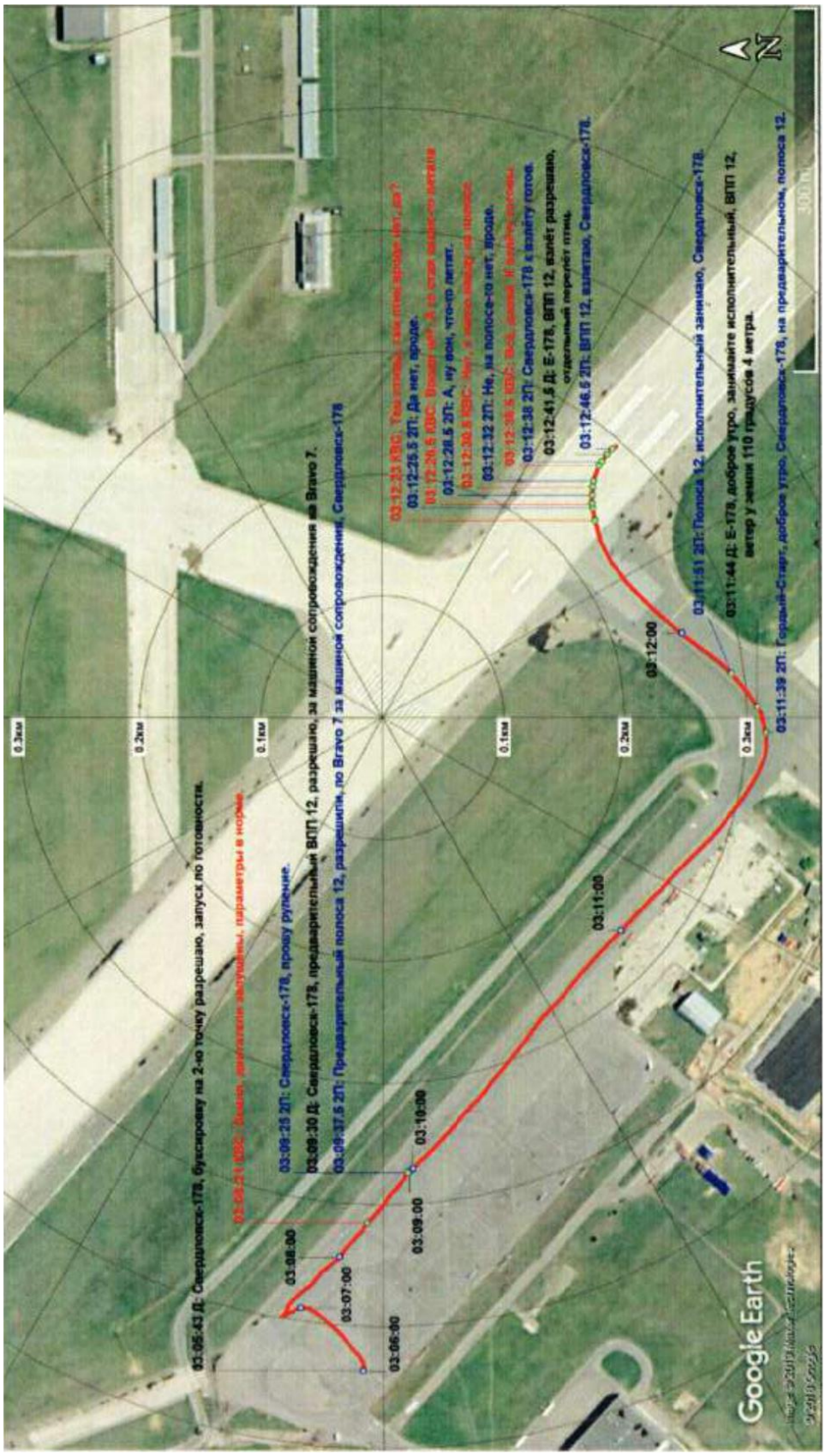



*Figure 72. Path of the aircraft across the airport before takeoff, with crew communications.*

Image translation:

*3:05:43 ATC: Sverdlovsk-178, pushback on two authorized, start engines when ready.*

*03:0?:21 Captain: [Illegible][40], engines are running, parameters normal.*

*03:09:25 FO: Sverdlovsk-178, request taxi.*

*03:09:30 ATC: Sverdlovsk-178, expect Runway 12, cleared to follow the escort vehicle onto Bravo 7.*

*03:09:37.5 FO: Expect Runway 12, cleared via Bravo 7 behind the escort vehicle, Sverdlovsk-178.*

*03:11:39 FO: Tower, good morning, Sverdlovsk-178, expecting Runway 12.*

*03:11:44 ATC: E-178, good morning, enter position on Runway 12, wind across the ground is 110 degrees at 4 meters per second.*

*03:11:51 FO: Runway 12, enter position, Sverdlovsk-178.*

*03:12:23 Captain: There are, there are hardly any birds there, no?*

*03:12:25.5 FO: Yeah no, hardly.*

*03:12:26.5 Captain: Hardly any? But some kind of flock is flying there.*

*03:12:28.5 FO: Ah, well, there something's flying.*

*03:12:30.5 Captain: No, I mean on the runway.*

*03:12:32 FO: No, there are hardly any on the runway.*

*03:12:3?.5 Captain: That's it, let's go. We're ready for takeoff.*

*03:12:38 FO: Sverdlovsk-178, ready for takeoff.*

*03:12:41.5 ATC: E-178, Runway 12, cleared for takeoff, isolated bird activity.*

*03:12:46.5 FO: Runway 12, taking off, Sverdlovsk-178.*

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[40] *Translator's note: The quality of the diagram is low and some words are not legible. These are marked with the word [Illegible]. These words were presumably audible on the recording and are known to the MAK, so the use of "illegible" should not be taken to mean that they were inaudible.*

During pushback, between 03:07:30 and 03:08:20, the flight recorders registered the engine startup, first the right then the left. During engine start the crew verified the engines' operation without incident. No signs of abnormal engine operation were recorded. After engine start the crew completed the after start checklist. The checklist was completed fully and without incident.

After engine start, the flaps and slats were extended to the CONF 1+F position (flaps 10˚, slats 18˚).

Between 03:08:55 and 03:09:20, the crew carried out the control checks without incident.

At 03:09:25, the crew requested permission to taxi. After receiving permission from the controller—"*Sverdlovsk-178, expect Runway 12, cleared to follow the escort vehicle onto Bravo 7"*—the aircraft taxied along taxiway B5. During taxi, the crew verified the operation of the brakes and completed the before takeoff checklist "down to the line." The checklist was completed fully and without incident.

After entering taxiway B7, the crew requested permission to enter the takeoff position. The Captain said: *"Yes, tell him we're there. So we don't end up sitting there on the threshold."* At 03:11:44 the Tower controller cleared them into the takeoff position: *"E-178, good morning, enter position on Runway 12, wind across the ground is 110 degrees at 4 meters per second,"* and the crew confirmed receipt of the information. After receiving clearance into position, the crew carried out the before takeoff checklist "below the line." The checklist was completed fully and without incident.

An analysis of the recorded information permits the conclusion that the flight crew completely carried out all system and equipment checks before takeoff. The crew made no remarks about the functioning of any systems.

At 03:12:42, after the crew reported ready for takeoff, the Tower controller granted takeoff clearance: *"E-178, Runway 12,*[41] *cleared for takeoff, isolated bird activity."*

Before takeoff, the weight of the aircraft was ≈82,200 kg; the calculated stabilizer position was 0.7˚; the flaps and slats were set to CONF 1+F (flaps 10˚, slats 18˚); the calculated V-speeds were $V_1$=$V_R$=166 kt, $V_2$ 168 kt; the engines were set to the FLEX 49 regime; and the beacon lights were off.

***Note:*** *1. If maximum rated thrust is not needed for takeoff, then a reduced thrust takeoff may be carried out. The required $N_1$ is calculated based on the FLEX temperature determined by the crew and entered into the FMGS MCDU. The FLEX temperature is a function of the aircraft weight and outside conditions. It guarantees that the required takeoff characteristics will be achieved (for more information, see FCOM, section PER-THR-FLX).*

*2. While preparing for the flight, the crew mentioned their calculated speeds several times. During the briefing, they stated: "preliminarily, 1-6-9, 1-6-9, 1-7-1." After receiving the manifest and documentation from the cabin attendants, the First Officer corrected the calculations at 03:04:17: "165, 165, 168, FLEX 49." A short time later, at 03:04:40, he made a further adjustment to the calculations: "165, 165, 167…." The Captain repeated the given values, and at that moment, according to the FDR, the commanded speed was entered as 167 kt. At 03:10:54, while completing the before takeoff checklist "down to the line," both crewmembers again confirmed the*

[41] The magnetic course on takeoff was 121˚.

*calculated speeds "1-6-5, 1-6-5, 1-6-7." In the OFP (Operational Flight Plan) the crew entered the values 166, 166, and 168. These values were derived by the manufacturer during the computer modeling of the flight.*

The Captain's and First Officer's flight directors were turned off. After placing the thrust levers into the FLEX regime, the SRS regime engaged in the longitudinal channel; no regime was selected in the lateral channel. The autothrottle (AT) was engaged, but not active. On the System Display (SD), the engine page was displayed until the end of the flight.

Fig. 73 shows the trajectory of the aircraft from takeoff to landing.

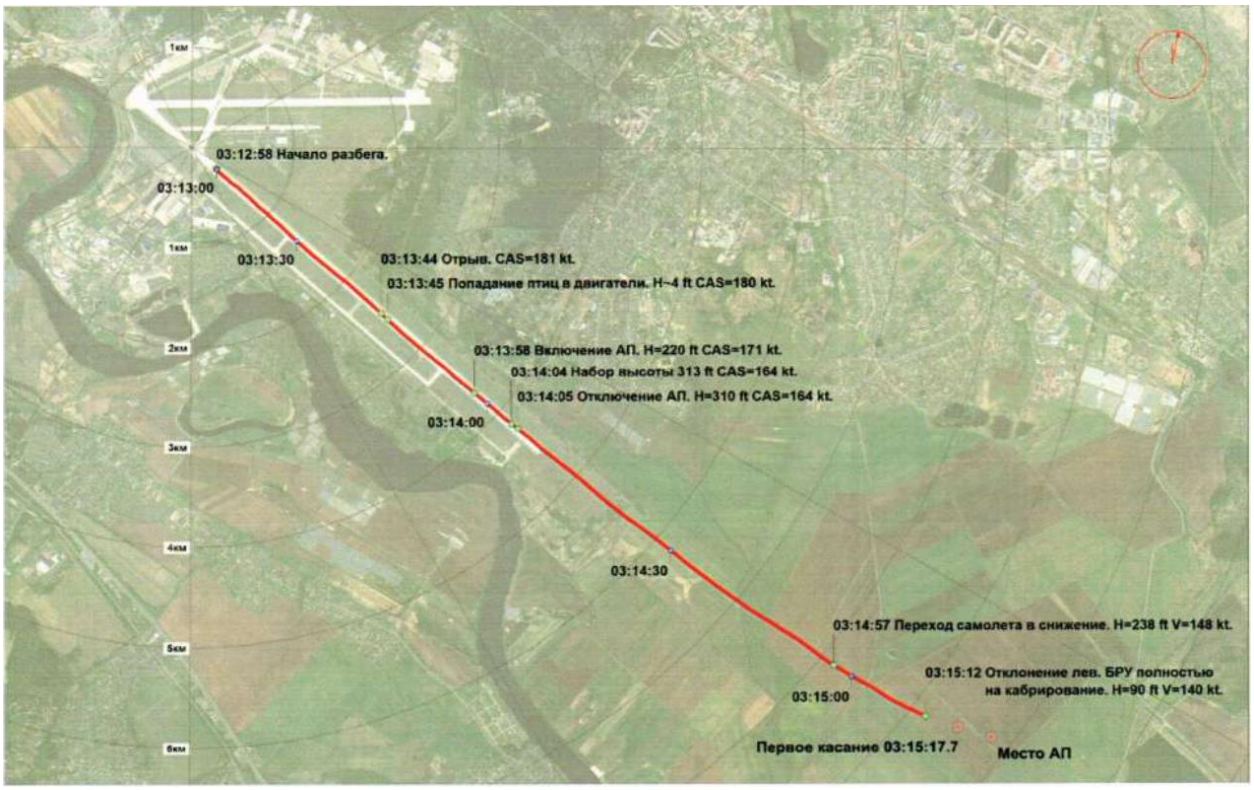



*Figure 73. Trajectory of the aircraft from takeoff to landing.*

Image translation:

*03:12:58 Start of takeoff roll*

*03:13:44 Liftoff. CAS=181 kt.*

*03:13:45 Ingestion of birds into the engines. H ~4 ft, CAS = 180 kt.*

*03:13:58 Autopilot engaged. H = 220 ft, CAS = 171 kt.*

*03:14:04 Max height 313 ft, CAS = 164 kt.*

*03:14:05: Autopilot disengaged. H = 310 ft, CAS = 164 kt.*

*03:14:17 Aircraft begins descending. H = 238 ft, V = 148 kt.*

*03:15:12 Left side stick positioned full nose up. H = 90 ft, V = 140 kt.*

*First touchdown at 03:15:17.7*

*Accident site*

Graphs of basic parameters are shown in Fig. 35-39. The takeoff roll began at 03:12:58. The engines were in the FLEX 49 regime and the actual $N_1$ corresponded to the commanded $N_1$. The Captain was the pilot flying. At the start of the takeoff roll, the aircraft was about 320 m from the threshold of Runway 12. The takeoff roll began after the aircraft stopped on the runway; no braking action was used during engine runup. During the takeoff roll the crew monitored the engine parameters and acceleration.

At 03:13:40, after the First Officer called out *"$V_1$"* and *"Rotate,"* the left side stick was moved back in order to achieve the takeoff angle of attack. Liftoff occurred at 03:13:44 at a speed of ≈181 kt (see Fig. 35), which is significantly higher than the calculated $V_2$ speed (takeoff safety speed). The engine parameters were as follows: left engine – $N_1$ = 91.6%, $N_2$ = 98.5%, EGT = 799˚; right engine – $N_1$ = 91.7%, $N_2$ = 98.3% EGT = 767˚ (see Fig. 37).

Up to the moment of liftoff, no commands or parameters indicated any abnormal operation or failure of any system, including the engines.

Almost immediately after liftoff, at 03:13:45 (indicated by vertical red lines on Fig. 35-38), at a height of between 2 and 4 feet (≈1 m), increased vibrations began to be recorded in the low pressure rotors of both engines up to the maximum measurable value (9.8 units), without the thrust lever positions having changed. The vibrations in the left engine reached the maximum value in a single recording interval, or about 1 second, and the right engine in ≈4 seconds. This vibration level was recorded until the end of the flight. A corresponding indication should have been presented to the crew in the form of an ECAM Advisory[42] on the system display (and the vibration indication would been flashing).

At this stage, the cockpit voice recorder captured loud noises characteristic of a birdstrike. At the moment of onset of the abnormal situation, the aircraft was about 2,600 m from the threshold of Runway 12 and about 2,000 m from the end of the runway. The crew did not consider the possibility of rejecting the takeoff.

From this point, the $N_1$ and $N_2$ values on the left engine began to decrease, while the exhaust gas temperature began to increase. The commanded $N_1$ on the left engine remained unchanged at 90%[43] (see Fig. 38).

Right engine $N_1$ decreased to ≈88.5% (in accordance with the commanded $N_1$, which also decreased),[44] and $N_2$ was ≈96.5% with a simultaneous decrease in exhaust gas temperature.

After approximately one second, a discrete command to open the left engine thrust reverser door locks was recorded ("REVERSER UNLOCK ENG. 1"); [45] the discrete command

[42] This is the lowest priority indication according to Airbus's warning philosophy; above ADVISORY is CAUTION, while WARNING holds the highest priority.
[43] The margin of error for the commanded $N_1$ parameters is 2%.
[44] For an explanation of the possible reasons for the decrease in commanded $N_1$, see section 1.16.3. of this report.
[45] For more information, see section 2.2.1 of this report.

to fully open the reverser door locks (FULDEP1) was not recorded. This discrete command remained active until the end of the flight. A message about the open reverser doors was provided to the crew in the form of a single chime, a master caution light,[46] and a corresponding ECAM amber caution message. Fig. 74 shows a reconstruction of the instrument indications in the cockpit at 03:13:48, according to the manufacturer.

*Figure 74. Reconstruction of instrument indications at 03:13:48*

An analysis of flight recorder data and the results of inspections of the runway and the accident site led to the conclusion that a birdstrike involving a flock of gulls took place immediately after liftoff from the runway (see section 1.16.2. of this report), causing damage to both engines (see section 1.16.3. of this report). As a result, the left engine thrust decreased practically to idle, and right engine thrust decreased by about 20% (for more information about the remaining engine thrust, see section 1.16.4.2. of this report).

The birdstrike was also confirmed by video footage (passengers recorded video through the windows during the takeoff roll [Fig. 75]).

*Figure 75. The moment that A321 VQ-BOZ struck a flock of gulls (left side).*

Four seconds after liftoff from the runway, the First Officer said, *"Climb;"*[47] the Captain did not react. Judging by the recorded conversations, at this stage the crew were focused on the

[46] The master caution light remained active until the end of the flight.
[47] The CVR did not record the word "Positive."

warnings about the unlocked reverser doors on the left engine (at 03:13:50 the First Officer said: *"So. Engine one. Reverse mode;"* the Captain replied, *"Check."*).

After liftoff rom the runway, the aircraft entered a climb with a pitch angle of 12˚-13˚; the landing gear remained extended, and the flaps/slats were in configuration CONF 1+F (the position of the flaps and slats did not change until the end of the flight). The indicated airspeed reached a maximum value of 183 kt and then began to decrease.

Because of the difference in engine thrust, the aircraft began to yaw to the left, leading to a right sideslip (see Fig. 36; on this diagram a right sideslip is indicated by positive values) and a bank to the left. At this stage the Captain did not touch the pedals; the yaw damper deflected the rudder to the right to counter the sideslip.

No later than 03:13:46.5, a BETA TARGET[48] indication appeared on the PFD, and the indicated airspeed was 182 kt. According to the DAR, the commanded sideslip angle at this stage of the flight was ≈2˚ left, and the actual sideslip angle was 2.8˚ to the right.

The control system remained in Normal Law until the end of the flight, so with the side stick in the neutral roll position, the control system automatically deflected the ailerons and spoilers on the appropriate wing in order to maintain zero roll rate. At the same time, the Captain periodically made roll inputs.

> ***Note:*** *FCOM. DSC-27-20-10-30 pg. ½. AIRCRAFT SYSTEMS. FLIGHT CONTROLS. FLIGHT CONTROL SYSTEM – NORMAL LAW*
> *When the aircraft is in the "in flight" mode, normal law combines control of the ailerons, spoilers (except No. 1 spoilers), and rudder (for turn coordination) in the sidestick. The pilot does not need to use the rudder for turn coordination. While the system thereby gives the pilot control of the roll and heading, it also limits the roll rate and the bank angle, coordinates the turns, and damps the dutch roll. The roll rate requested by the pilot during flight is proportional to the sidestick deflection, with a maximum rate of 15˚/s when the sidestick is at the stop.*[49]

At 03:13:56, at a height of ≈170 ft[50] and an airspeed of 174 knots, the right pedal was deflected forward. Fig. 76 shows a reconstruction of the instrument indications in the cockpit immediately before the pedal deflection began.

[48] For more information see section 1.18.1 of this report.
[49] When the sidestick is in the neutral roll position, the commanded (total) roll rate will be equal to zero.
[50] Henceforth, unless otherwise indicated, radio altitude is used. There were no significant terrain variations in the area of the accident.

*Figure 76. Reconstruction of instrument indications at 03:13:56.*

The deflection of the pedals to the 8˚ position (the maximum possible pedal deflection is ±30˚) and their maintenance in that position resulted in the elimination of the right sideslip and the development of a 3˚ left sideslip. This value exceeded the commanded sideslip angle, generating a rightward lateral load of 0.035 G. Following the reduction in the right sideslip, the right wing spoilers retracted, while the left wing spoilers extended to the 1.5˚ position upon development of the left sideslip.

At 03:13:59, the No. 1 (left) autopilot was engaged, and the Captain said, *"Autopilot one."* At the moment that the autopilot was engaged, the aircraft's height was ≈230 feet, its airspeed was 171 knots, its pitch angle was ≈12˚ nose up, and the bank angle was essentially zero (Fig. 77). Before engagement of the autopilot, the rudder trim did not move and remained in the neutral position; the pressure on the rudder pedals was maintained. The First Officer confirmed the engagement of the autopilot: *"Check."*

*Figure 77. Reconstrruction of instrument indications at 03:13:59.*

The autopilot's pitch channel was active in "AP – PITCH TAKEOFF"[51] mode and its lateral channel was in "AP – NAV" mode. At this point the engine parameters were as follows: left engine – $N_1$ = 39.7%, $N_2$ = 87.9%, EGT = 915˚; right engine – $N_1$ = 88.8%, $N_2$ = 96.5%, EGT = 718˚. According to the FDR, the commanded $N_1$ values were 90% for the left engine and 88% for the right engine.

After engagement of the autopilot, the pitch angle was automatically reduced to ≈6˚ nose up, which halted the decrease in airspeed (the minimum airspeed value at this stage of the flight was 164 kt). The takeoff safety speed ($V_2$) was 167 kt. The FMGS first recognized the occurrence of an engine failure at an airspeed of around 180 kt, and it was this speed that the autopilot should have sought to maintain in the event of a failure, according to its working logic (see Note below). This is guaranteed by the by the flight path angle protection (a minimum vertical speed of +120 ft/min or 0.6 m/s).

***Note:*** *FCOM. DSC-22 30-80-20 pg. 1/6. SRS (SPEED REFERENCE SYSTEM).*

*GENERAL*

*The SRS mode controls pitch to steer the aircraft along a path in the vertical plan at a speed defined by the SRS guidance law.*

*ENGAGEMENT CONDITIONS*

*The SRS mode engages automatically when the thrust levers are set to the TOGA or FLX/MCT detent (when a Flex takeoff temperature or Derated takeoff has been selected), providing:*

- *$V_2$ has been inserted in the MCDU PERF TAKEOFF page*
- *The slats are extended*
- *The aircraft has been on ground for at least 30 s.*

[51] According to the manufacturer, this regime corresponds to the SRS (Speed Reference System) regime.

*GUIDANCE*
*In SRS mode, the aircraft maintains a speed target equal to $V_2$+10 kt in normal engine configuration. When the FMGS detects an engine failure, the speed target becomes the highest of $V_2$ or current speed, limited by $V_2$+15 kt.*
*The SRS guidance law also includes:*

- *Attitude protection to reduce aircraft nose-up effect during takeoff (18˚ or 22.5˚ maximum in case of windshear)*
- *Flight path angle protection that ensures a minimum vertical speed of 120 ft/min*
- *A speed protection limiting the target speed to $V_2$+15 kt.*

At 03:14:04, the aircraft reached a height of ≈315 ft (the maximum height achieved during the accident flight), which after accounting for terrain was ≈300 ft above the runway level.

After engaging the autopilot, the Captain issued the command, *"ECAM action."* The First Officer started to read off the ECAM messages:[52] *"Engine one reverse unlocked, thrust levers one IDLE."* Completion of the procedure was interrupted by an autopilot disconnect warning. Although the First Officer called out *"Confirm thrust,"* and the Captain replied *"Check,"* the left thrust lever was not moved and remained at the 34˚ position.

After the engagement of the autopilot, the rudder trim moved to a value of 5.2˚ right and remained in this position until the end of the recording. The autopilot disengaged at 03:14:06. Fig. 78 shows a reconstruction of the instrument indications in the cockpit immediately after the disconnection of the autopilot.

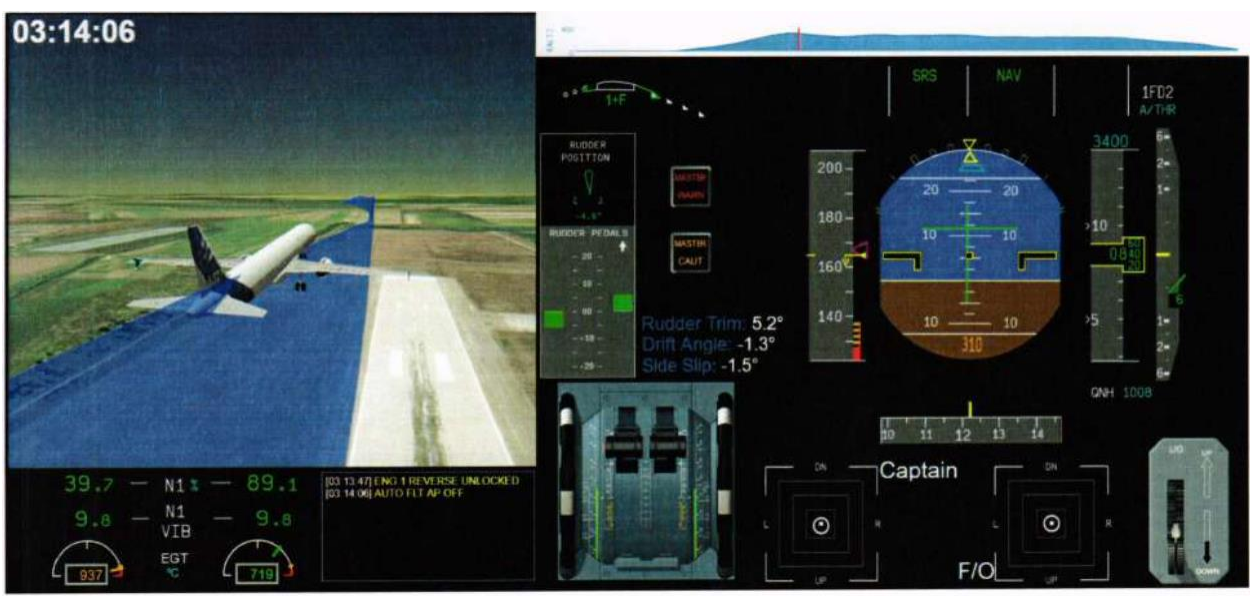



*Figure 78. Reconstruction of instrument indications at 03:14:06*

[52] Besides their headlines, the ECAM messages also include the required crew actions. Fig. 77 and other figures with reconstructed instrument indications only show the headlines of the messages in the order of their creation during the accident flight.

Based on the registration of the discrete parameter "AP OFF WARNING," the activation of the "MASTER WARNING," and the continuous aural alarm registered on the CVR, an "abnormal" autopilot disengagement (a disengagement for reasons other than the position of the autopilot button on the sidestick). (The disengagement of the autopilot took place automatically, according to its system logic, because of the deflection of the pedals away from the trimmed position above the disconnect threshold. For more information see section 2.2.2. of this report.) The flight crew did not cancel the aural and visual warnings, which continued to operate until the end of the flight. A red "AP OFF" message also appeared on the ECAM (see section 1.16.5. of this report).

At the moment of autopilot disconnection, the airplane was at a height of about 300 ft, the airspeed was ≈165 kt (with a positive trend), the pitch angle was 5.6˚ nose up, and the engine parameters were as follows: left engine – $N_1$ = 39.4%, $N_2$ = 86.3%, EGT = 934˚; right engine – $N_1$ = 89.1%, $N_2$ = 96.7%, EGT = 718˚.

It should be noted that at the moment that the autopilot was engaged, the flight director pitch bar[53] was not centered on the instrument (the FCTM recommends that the pilot follow the flight director pitch bar and remove any pedal force prior to engagement of the autopilot), which was the reason for the significant automatic nose down pitch input, and which led, under the actual flight conditions, to the airplane's entry into a descent. At 03:14:09, an EGPWS "DON'T SINK" warning sounded. During the remainder of the flight, this warning activated several more times (see Fig. 39).

> ***Note:*** *FCTM AS-FG-10-1 pg. ¾. RECOMMENDED PRACTICE FOR AUTOPILOT (AP) ENGAGEMENT.*
> *Before engaging the AP, the flight crew should:*
> - *Fly the aircraft on the intended path*
> - *Check on the FMA that the Flight Director (FD) is engaged with the appropriate guidance modes for the intended flight path. If not, set the FD on, and the appropriate guidance mode(s) as required*
> - *Center the FD bars with the aircraft symbol on the PFD.*
>
> *Note: engaging the AP while large orders are required to achieve the intended flight path may result in an AP overshoot of the intended vertical or lateral target. This situation can surprise the flight crew, due to the resulting large pitch/roll changes and thrust variations.*

After the autopilot disengaged, the Captain started to increase the pitch angle (and by extension the angle of attack) using the sidestick, which stopped the plane from descending, but caused the airspeed to decrease. From that point the pitch angle varied between 8.5˚ and 13˚ nose up in accordance with the Captain's inputs.

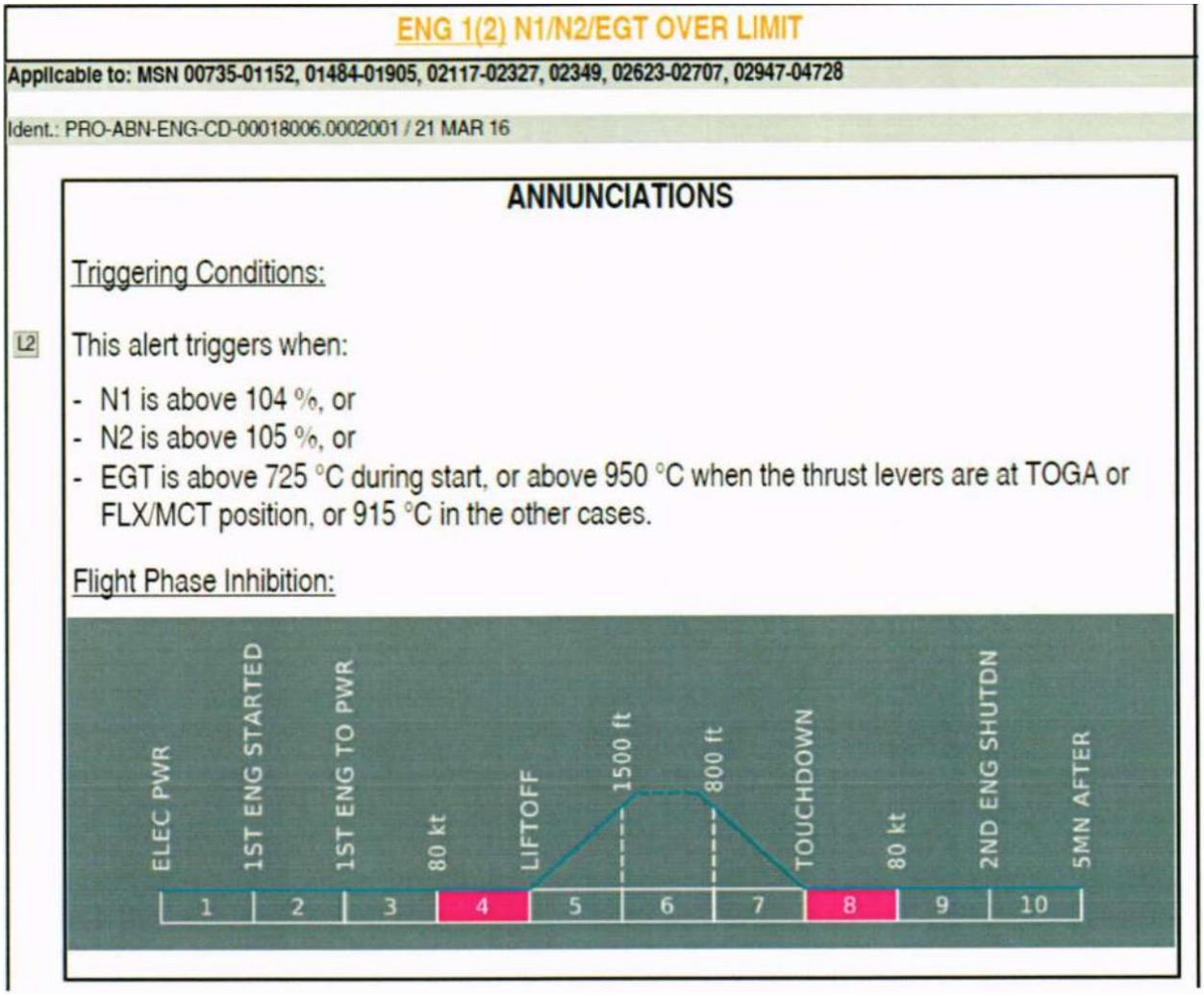
At 03:14:11, the Captain attempted to inform the ground control about the abnormal situation: *"PAN-PAN, PAN-PAN, PAN-PAN, Sverdlovsk…"* This phrase was not finished, and the controller did not answer.

The pedal deflection began to smoothly decrease (see Fig. 36). As the pedals approached the neutral position, the airplane again began to turn to the left, and a right sideslip developed, leading to an automatic increase in the aileron and spoiler deflection on the right wing (in order guarantee zero roll rate with the sidestick in the neutral position). The deflection of the control

[53] In fact the flight director arrow was commanding a 6˚decrease in pitch angle.

surfaces led to increased drag and an additional decrease in speed, which required even more control deflection in order to maintain balance. The airspeed fell below $V_2$ and continued to decrease.

At 03:14:17, the left engine exhaust gas temperature reached the EGT red limit of 950˚C for the FLEX regime. An amber "ENG 1 EGT OVERLIMIT" message appeared on the ECAM (Fig. 79).


ENG 1(2) N1/N2/EGT OVER LIMIT

Applicable to: MSN 00735-01152, 01484-01905, 02117-02327, 02349, 02623-02707, 02947-04728

Ident.: PRO-ABN-ENG-CD-00018006.0002001 / 21 MAR 16

ANNUNCIATIONS

Triggering Conditions:

L2 This alert triggers when:

- N1 is above 104 %, or
- N2 is above 105 %, or
- EGT is above 725 °C during start, or above 950 °C when the thrust levers are at TOGA or FLX/MCT position, or 915 °C in the other cases.

Flight Phase Inhibition:



*Figure 79. The FCOM page for the ENG 1 EGT OVERLIMIT message (stages of flight where this message is inhibited are colored in)*

Because the ECAM was already displaying other messages and actions which the crew had not fulfilled,[54] and because the messages themselves were not cleared, this message could not have been in the crew's field of view.[55] This fact was confirmed while reconstructing the ECAM messages in the simulator (see the upper portion of Fig. 80). If the crew had cleared the

[54] The Commission came to this conclusion based on the lack of recorded crew conversations about completing the actions related to any of the ECAM messages, as well as the absence of recorded parameters associated with those actions on the FDR. In their surveys, the crewmembers also did not mention completing the ECAM actions.
[55] In such a case a green arrow, pointing downward, indicates the presence of additional text.

message about the autopilot disengagement, then the message about the high exhaust gas temperature would have appeared in their field of view (see the lower portion of Fig. 80).

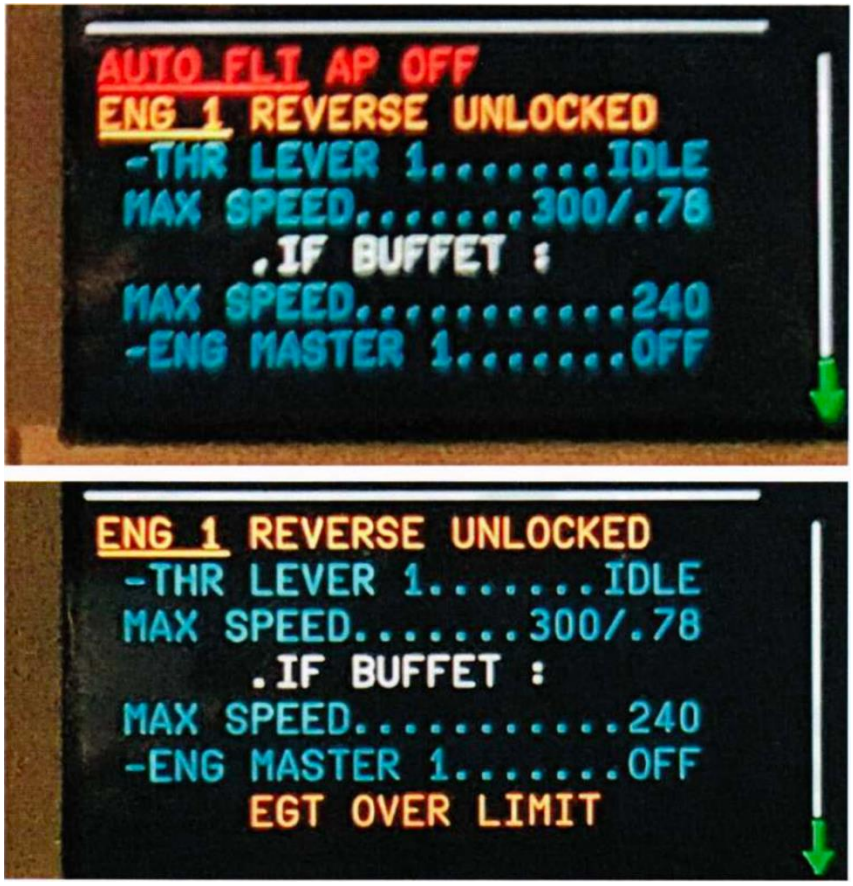



*Figure 80. Reconstruction of ECAM indications during the accident flight*

The exceedance of the red limit exhaust gas temperature continued for 19 seconds. After that the temperature decreased, but at 03:14:40 the limit temperature was exceeded again, and the warning was generated a second time. After a further 7 seconds, when the left engine was placed in the flight idle regime (described later in this section), the exhaust gas temperature dropped back below the limit. The crew did not discuss the temperature exceedance.

At 03:14:20, both thrust levers were moved to the 42˚ position (corresponding to the TO/GA regime), and the commanded $N_1$ increased to 100% and 96% for the left and right engines respectively. At that moment the height of the airplane was 290 ft. The movement of the thrust levers did not result in a change to the operating regime of the left engine; the right engine thrust output did increase, but significant fluctuations in its operating parameters were observed (see section 1.16.3. of this report). The $N_1$ speed fluctuated within the 78-96% range (of which the upper bound corresponded to the commanded $N_1$); $N_2$ fluctuated between 96 and 101%; and fuel flow fluctuated between 2500 and 4700 kg/h. The CVR recorded banging sounds associated with these fluctuations. No attempts were made to reduce the operating regime of the right engine. The right thrust lever remained in the TO/GA regime and continued its unstable operation until the end of the FDR recording.

At this point, according to the PFR, an “ENG 1 STALL” condition was registered (see section 1.16.5. of this report). This condition should be accompanied by an amber ECAM

message. However, according to the FCOM, during the stage of flight from liftoff to 1,500 feet this message is inhibited (Fig. 81). An analogous condition was not generated for the right engine, even though it was exhibiting signs of a compressor stall.

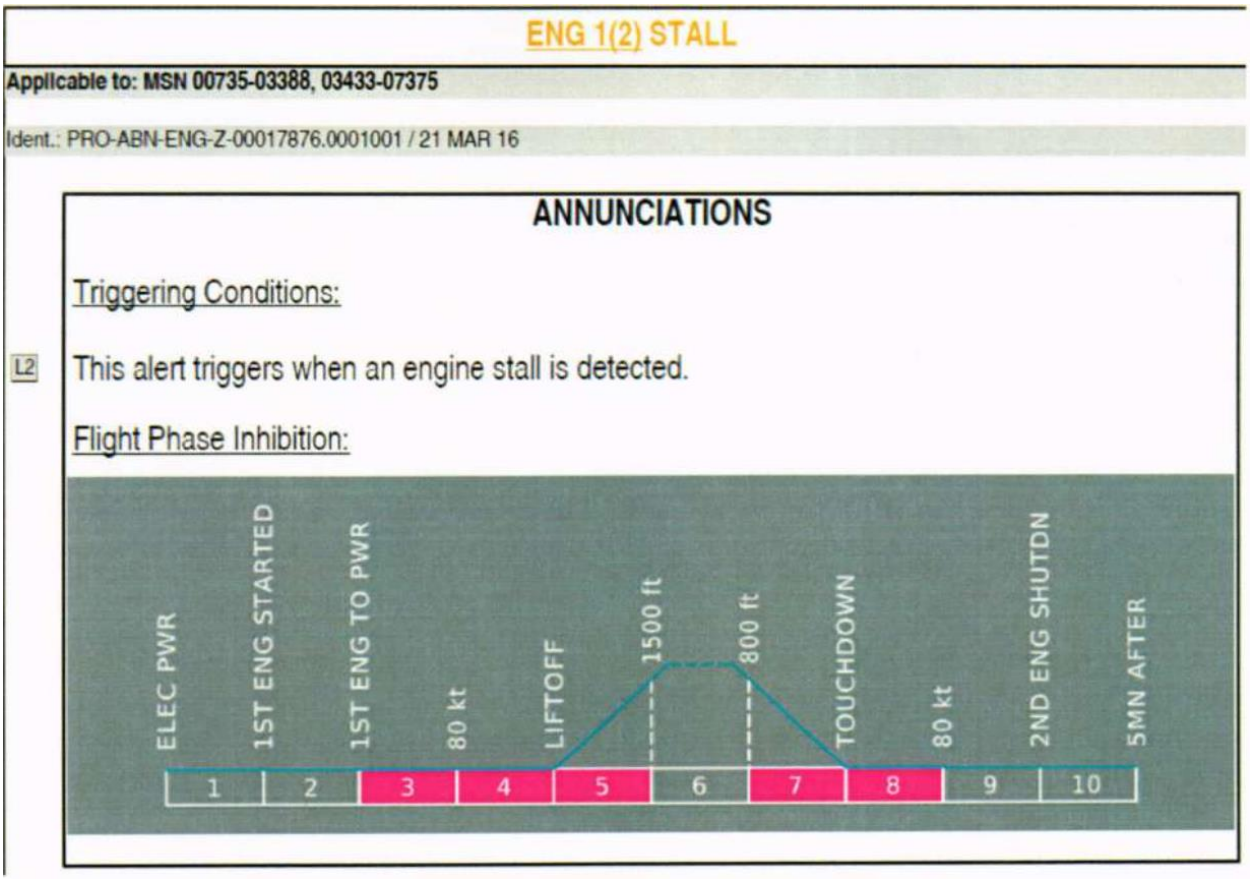



*Figure 81. The FCOM page for the ENG 1 STALL message (stages of flight where this message is inhibited are indicated in color)*

Eight seconds after TOGA power was commanded, the left thrust lever was moved to the 25˚ (CL) position, and the commanded $N_1$ decreased to 86%. The left engine did not react; the actual $N_1$ speed remained around 39%. The height of the aircraft was 280 ft and its airspeed was 155 kt.

At 03:14:29, the Captain informed the First Officer of the autopilot disconnect and issued a command to monitor airspeed: *"Autopilot off. Watch speed."* The First Officer did not reply. At that very moment the tower controller contacted the flight. The Captain reported the abnormal situation and the failure of one engine: *"PAN-PAN, PAN-PAN, PAN-PAN. SVERDLOVSK 1-7-8. One engine failure."* After this, he ordered the First officer to request permission from the controller to reverse course for approach and landing.

At 03:14:41, the First Officer confirmed the engine failure to the controller, and at 03:14:55 he requested an approach and landing on the opposite course. The controller granted permission at 03:15:00. The crew took no action to accomplish the turnback and did not discuss the logistics of returning to the airport.

At this stage the flight continued at a height of about 240 ft, while the airspeed continued to decrease; the bank was virtually zero. The Captain's attempts to maintain height with

decreasing airspeed led to an increase in the angle of attack and an even greater increase in induced drag, causing further loss of airspeed. The deflection of the right pedal gradually decreased. The sideslip angle increased to ≈3˚ right, with a commanded sideslip angle of 2.5˚ left. The left aileron was deflected to the 16˚ position, and the right aileron to the 7˚ position; the spoiler deflection on the right wing was as follows: spoiler 3 - ≈7˚; spoilers 2, 4, and 5 - ≈10˚. The deflection of the ailerons and spoilers increased drag even further.

**Note:** The ailerons and spoilers work together in flight. The aircraft has five spoiler sections per wing, which are numbered from 1 to 5. The No. 1 spoilers are not used in flight. The maximum deflection is 7˚ on the No. 3 spoilers, and 35˚ on spoilers Nos. 2, 4, and 5. The range of aileron deflection is ±25˚. When the flaps are extended, both ailerons "hang" down by 5˚.

At 03:14:47, at a height of 240 ft and an airspeed of 152 kt, the left thrust lever was moved to the IDLE position. After the thrust lever was moved to the IDLE position, a decrease in $N_1$ and $N_2$ was registered, as well as a decrease in the left engine's exhaust gas temperature. Consequently, the actual $N_1$ speed started to reflect the commanded $N_1$. The left engine continued to operate in this regime until the end of the FDR recording; the Captain made no attempt to increase thrust on this engine.

The Captain's attempt to continue the flight without losing altitude despite a lack of thrust led to a further decrease in airspeed, and the airplane began to descend with an initial descent rate of 2-3 m/s (400-600 ft/min). At 03:14:58, the First Officer called the Captain's attention to their decreasing altitude: *"Altitude, altitude*." The Captain reacted by pulling up with the left sidestick. The pitch angle increased to ≈12˚ nose up and the airspeed decreased to 145 kt (Fig. 82).

*Figure 82. Reconstruction of instrument indications at 03:14:58*

As the airspeed decreased, maintaining level flight required a higher angle of attack. The aircraft's control system was operating in Normal Law. Around 03:15:00, the total angle of attack reached 12.5˚ (the AOAprot value under the present conditions), triggering the Alpha

Protection system.[56] At the moment that the Alpha Protection activated, the aircraft was descending through 200 ft, and its airspeed was 144 kt.

> ***Note:*** *During the accident flight, all three angle of attack sensors provided trustworthy information; therefore the high angle of attack protection system used a "total" value, equal to the average value between the left and right sensors mounted on the left and right sides of the aircraft.*

When the angle of attack reaches AOAprot, the system will automatically hold this angle when the sidestick is in the neutral position to prevent any further increase. If the sidestick is moved in the nose up direction, the pilot can increase the angle of attack up to the maximum allowable angle of attack (αMAX) under full deflection of the sidestick. The protection system remained active until the end of the flight because the Captain maintained his nose-up sidestick inputs.

Between 03:15:03 and 03:15:04, the EGPWS issued a "TERRAIN AHEAD. PULL UP" warning. By that point the height had reduced to 180-170 ft, and the aircraft was descending with a vertical speed of 3-4 m/s (Fig. 83). Because of the nose-up inputs on the left sidestick, the angle of attack fluctuated between 13˚ and 14.5˚. The left aileron was deflected to a position between 16˚ and 20˚, and the right aileron to a position between 7˚ and 11˚; the deflection of the right wing spoilers continued to increase to the following values: spoiler 3 - ≈7˚; spoilers 2, 4, and 5 - ≈18˚.

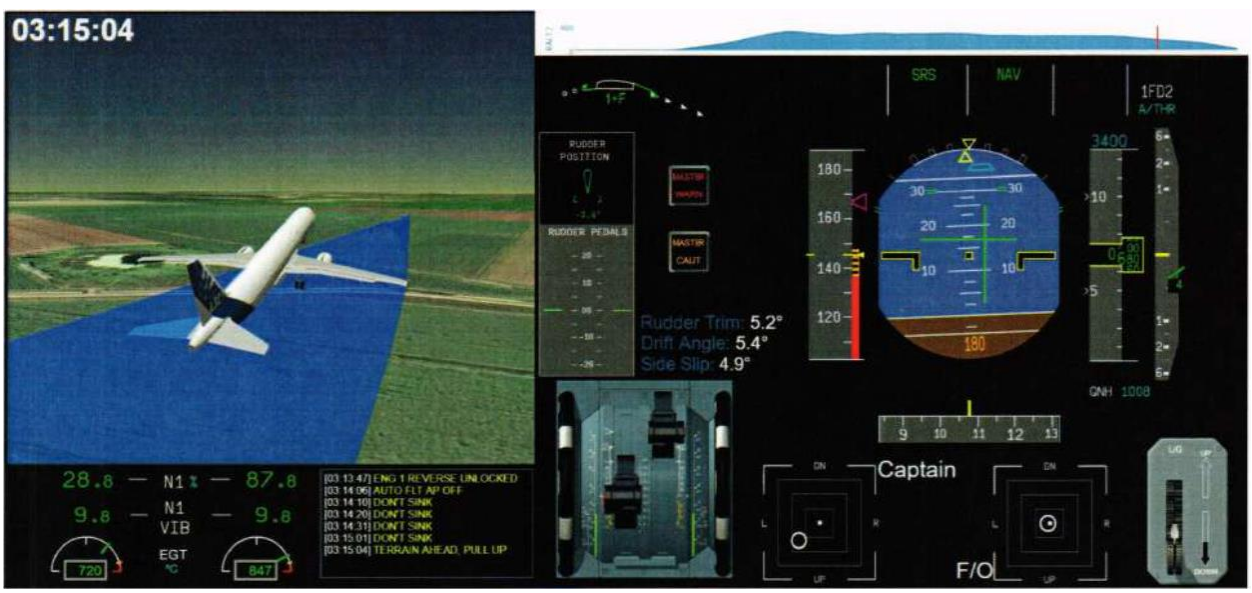


*Figure 83. Reconstruction of instrument indications at 03:15:04*

By 03:15:08, the rudder was in the neutral position, and the sideslip angle reached 5-6˚ right, while the commanded sideslip angle was 3˚ left.

At 03:15:10, at a height of 120 ft, the landing gear began to retract. The Captain did not order the retraction of the gear. According to his statement, the Captain retracted the gear unilaterally.

[56] For more information about this system, see section 1.18.5. of this report.

At 03:15:12, at a height of 90 ft and an airspeed of 140 kt, the left sidestick was moved to the full nose up position (from the Captain's statement: *"…near the ground, I instinctively pulled the sidestick back to the stop in order to rein in the rate of descent."*). Under maximum nose up deflection of the sidestick, the Alpha Protection threshold became αMAX, which was 15.5˚. The pitch angle increased to 13˚ nose up, and the total angle of attack reached 16.5˚ (in the dynamic situation the angle of αMAX was actually exceeded several times, which according to Airbus is consistent with the protection system logic when the target value is αMAX), as a result of which the stabilizer began to move in order to reduce the angle of attack. The high angle of attack protection system therefore worked normally, protecting the airplane from a stall and achieving the maximum possible lift coefficient prior to touchdown. Fig. 84 shows a reconstruction of the instrument indications in the cockpit after the sidestick was moved to full nose up.

*Figure 84. Reconstruction of instrument indications at 03:15:14*

At 03:15:15.625 the DAR recording ended.

Touchdown occurred at 03:15:17.7 on a magnetic heading of ≈94˚ and an airspeed of 136 kt. The final recorded flight path angle value (during the 4 seconds before touchdown) was -4.5˚, which at an airspeed of 135 kt corresponded to a descent rate greater than 5 m/s. Judging by the lack of any discrete command concerning stowage of the landing gear doors, the gear retraction cycle had not been completed at the moment of touchdown.[57] The pitch angle at touchdown was ≈8˚ nose up, and the bank angle was ≈2˚ to the right. The position of the left thrust lever still corresponded to the idle regime, and the right thrust lever was in the TO/GA regime, although the total remaining thrust available was less (see section 1.16.4.2. of this report). Almost immediately after the first touchdown, the FDR, CVR, and QAR ceased recording, most likely due to a loss of electrical power. Based on the examination of the accident site and the flight crew statements, the engines were shut down after the airplane came to a stop.

Considering all of the above, the control system operated in accordance with Normal Law throughout the flight. The fuel fire valves and HP fuel shut-off valves for both engines were in the open position until the end of the recording, and the engines did not shut off prior to

[57] This was also confirmed during the wreckage examination after the accident (see section 1.3. of this report).

touchdown. During the flight there were no hydraulic leaks nor any computer failures or loss of electrical power. No command to the flight attendants to prepare the passenger cabin for an emergency landing was issued.

The Commission notes that this case is not the first incident involving the A320 family in which flight recorder data ceased to be recorded after a loss of electrical power from the main buses, leading to an inability to evaluate the actions of the crew in the final phase of the flight, including during the emergency evacuation (for more information see section 1.18.14 of this report). The Commission notes that an evaluation of the conduct of the emergency evacuation is one of the most important parts of an investigation into an accident or serious incident in which an evacuation was conducted. Investigative experience has shown that when an emergency evacuation is made after a forced landing against the will of the crew, inevitably resulting in an unexpected situation, the crew is placed into a state of stress which often leaves them unable to make timely decisions and take optimal actions (see, for example, the final report of the investigation into the aviation incident involving a Boeing 737 RRJ-95 in Yakutsk: https://mak-iac.org/upload/iblock/087/report_ra-89011.pdf). The lack of a timely emergency evacuation can create a significant and at times unacceptable flight safety risk.

The Commission also notes that the presence of a CVR recording of an emergency evacuation is insufficient to analyze its quality and adherence to established procedures. Investigative experience has shown that in stressful situations, timely and necessary commands are critically important but often are not issued, or are only partially issued, which can only be evaluated using of the FDR recording (for example, the timing and order of activation of the fire extinguishing systems, opening of doors, shutdown of engines and systems, etc.).

As such, the Commission disagrees with EASA's position concerning the inexpediency of providing backup power to the flight data recorder. The Commission notes that deficiencies revealed during the conduct of an emergency evacuation are often classified as unacceptable (red), and investigations of accidents and incidents are often the only objective source of information about evacuation hazards and the risks they create, because planned emergency evacuation training scenarios by no means replicate the psychological pressures of a real accident. The Commission considers it necessary to repeat its recommendation that backup power sources for the flight data recorder be installed.

***Note:*** *The MAK Commission continues to investigate an aviation incident involving an An-74TK-100 aircraft with registration RA-74044, which occurred on 03/08/2020 at Gao, Republic of Mali. Preliminary report: https://mak-iac.org/upload/iblock/b0b/pr-report_ra-74044.pdf.*

*During the investigation, it was discovered that during level flight, both generators failed consecutively, and the crew was unable to start the APU. The power supply to the flight recorders on this aircraft type permitted their continued operation (including full FDR functionality) for more than 20 minutes after the failure of the second generator (until a total loss of power occurred due to exhaustion of the batteries).*

*MAK specialists are also participating in the investigation of an aviation incident (on-ground fire) involving a Tu-204C aircraft registered RA-64-32, which occurred on 08/01/2022 at Hangzhou International Airport (PRC). The investigation is being led by Chinese authorities. The fire erupted on board the airplane prior to engine start. As a result, the alternate power source for the flight*

*recorders allowed the FDR and CVR to record all the necessary information in full.*

### 2.2. Analysis of Aircraft Systems Serviceability

There were no indications of any equipment failures prior to the moment of the bird strike.

#### 2.2.1. Analysis of the Reasons for the Activation of the "ENG 1 REVERSE UNLOCKED" Warning and Operation of the Left Thrust Reverser

Approximately one second after the bird strike, the FDR registered a discrete command concerning the unlocked condition of the left engine reverser door locks ("REVERSER UNLOCK ENG. 1"). Simultaneously, an "ENG I REVERSE UNLOCKED" message appeared on the ECAM, accompanied by a single chime and a master caution light.

According to the FCOM (PRO-ABN-ENG), this warning activates when the position sensors on one or more doors indicate a position other than stowed while the plane is in the air, or while on the ground in the absence of a command to deploy the reverser. On the accident flight, the plane was in the air at the moment that the warning was generated.

A description of the condition of the thrust reverser system components is included in section 1.3. of this report. A description of the design of the thrust reverser system is included in section 1.18.9.

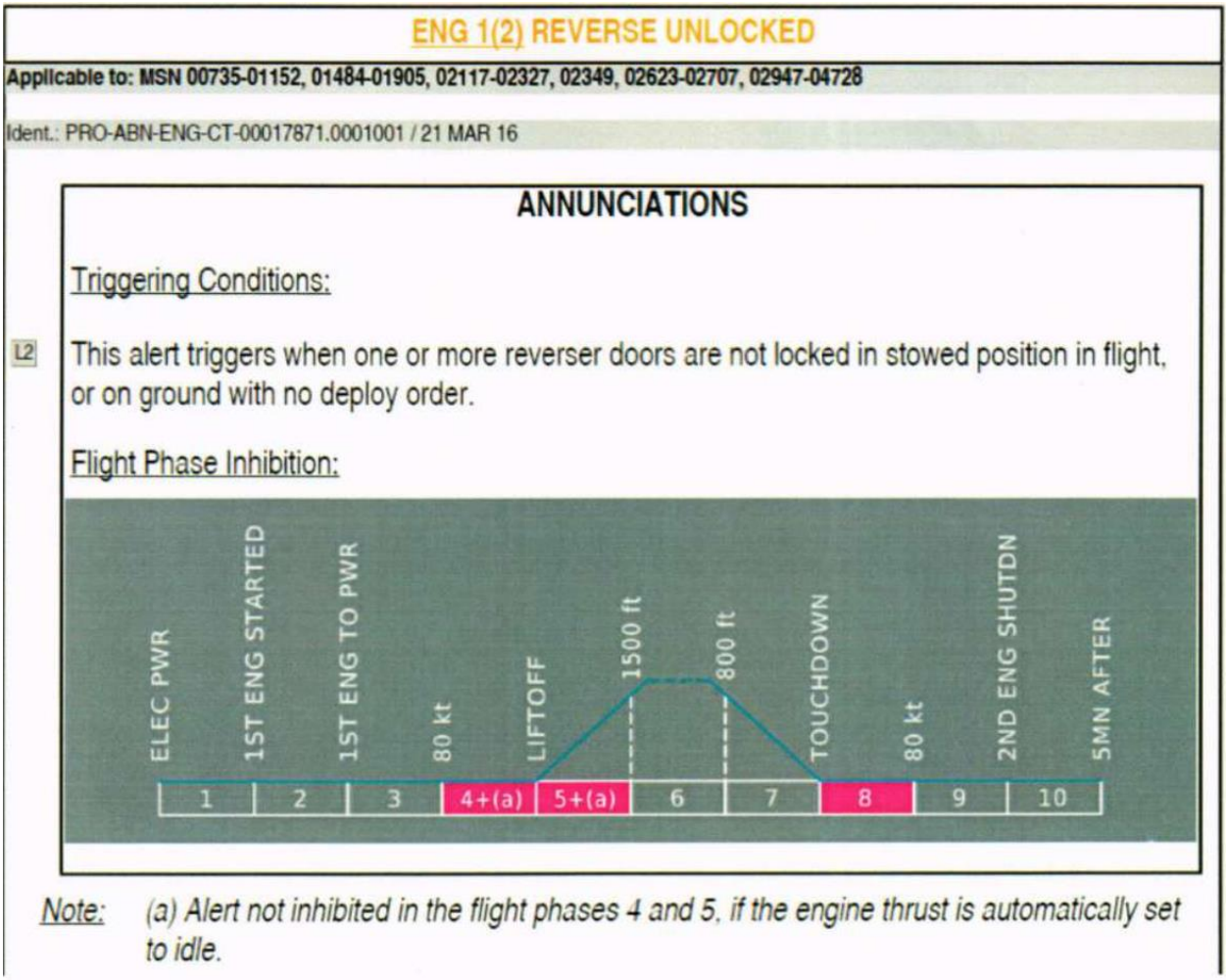
The research conducted by the Commission established that the four reverser door actuators on the left engine were in the stowed position, as they would be with the doors in the closed position. The extension length of all four actuator rods was 35-36 cm, corresponding to the length of the one accessible actuator rod from the right engine (the right engine did not experience a REVERSE UNLOCKED warning). The damage to the area around the rollers and on the aft part of the forward reverser frame occurred when the aircraft impacted the ground. All the primary reverser door locks left witness marks on the surrounding metal components. These facts, as well as the results of the mathematical model, support a conclusion that the left reverser doors were in the stowed position throughout the flight and did not affect the airplane's aerodynamic characteristics.

At the Commission's request, the manufacturer analyzed statistics related to "REVERSE UNLOCKED" warnings on CFM-56 engines following bird strikes. Since 2000, four such cases had been entered into the manufacturer's database. In the case involving the heaviest damage, the primary locks on two of the four reverser doors departed the stowed position during the bird strike, but the doors were held shut by the secondary locks. The thrust reverser did not actuate in any of the cases. The conclusions concerning the activation of the warning in the case of A321 VQ-BOZ match the conclusions in previous cases.

Therefore, based on the information from the reverser door position sensors, and the discovery of bird fragments on the left engine's exterior cowling, the "ENG 1 REVERSE UNLOCKED" warning most probably activated because a bird struck one of the reverser doors, causing at least one door position sensor to indicate a non-stowed condition.

The Commission also notes that the version of the FCOM in force at the time of the accident indicated that the activation of this warning is inhibited during the initial climb phase of

flight (Fig. 85) if an automatic reduction in thrust to idle does not occur. According to the FCOM (DSC-70-70 pp. 8-12), the FADEC will automatically reduce thrust to idle in the event of an uncommanded reverser deployment in flight. During the accident flight, the reverser doors did not open and no automatic reduction in thrust occurred. Therefore, the activation of the warning contradicted the FCOM provisions. This discrepancy drew the attention of the manufacturer. According to the manufacturer's conclusions, the functioning of the warning was correct; however the information in the FCOM was incorrect. The FCOM was correspondingly amended during the course of the investigation.


ENG 1(2) REVERSE UNLOCKED

Applicable to: MSN 00735-01152, 01484-01905, 02117-02327, 02349, 02623-02707, 02947-04728

Ident.: PRO-ABN-ENG-CT-00017871.0001001 / 21 MAR 16

ANNUNCIATIONS

Triggering Conditions:

L2 This alert triggers when one or more reverser doors are not locked in stowed position in flight, or on ground with no deploy order.

Flight Phase Inhibition:



Note: (a) Alert not inhibited in the flight phases 4 and 5, if the engine thrust is automatically set to idle.

*Figure 85. FCOM excerpt concerning the ENG 1 REVERSE UNLOCKED message on the day of the accident (stages of flight where this message is inhibited are highlighted in color)*

### 2.2.2. Analysis of the Reasons for Autopilot Disengagement

This section concerns the operation of the autopilot during the accident flight. Fig. 86 shows a graph of parameters which led to the disengagement of the autopilot.

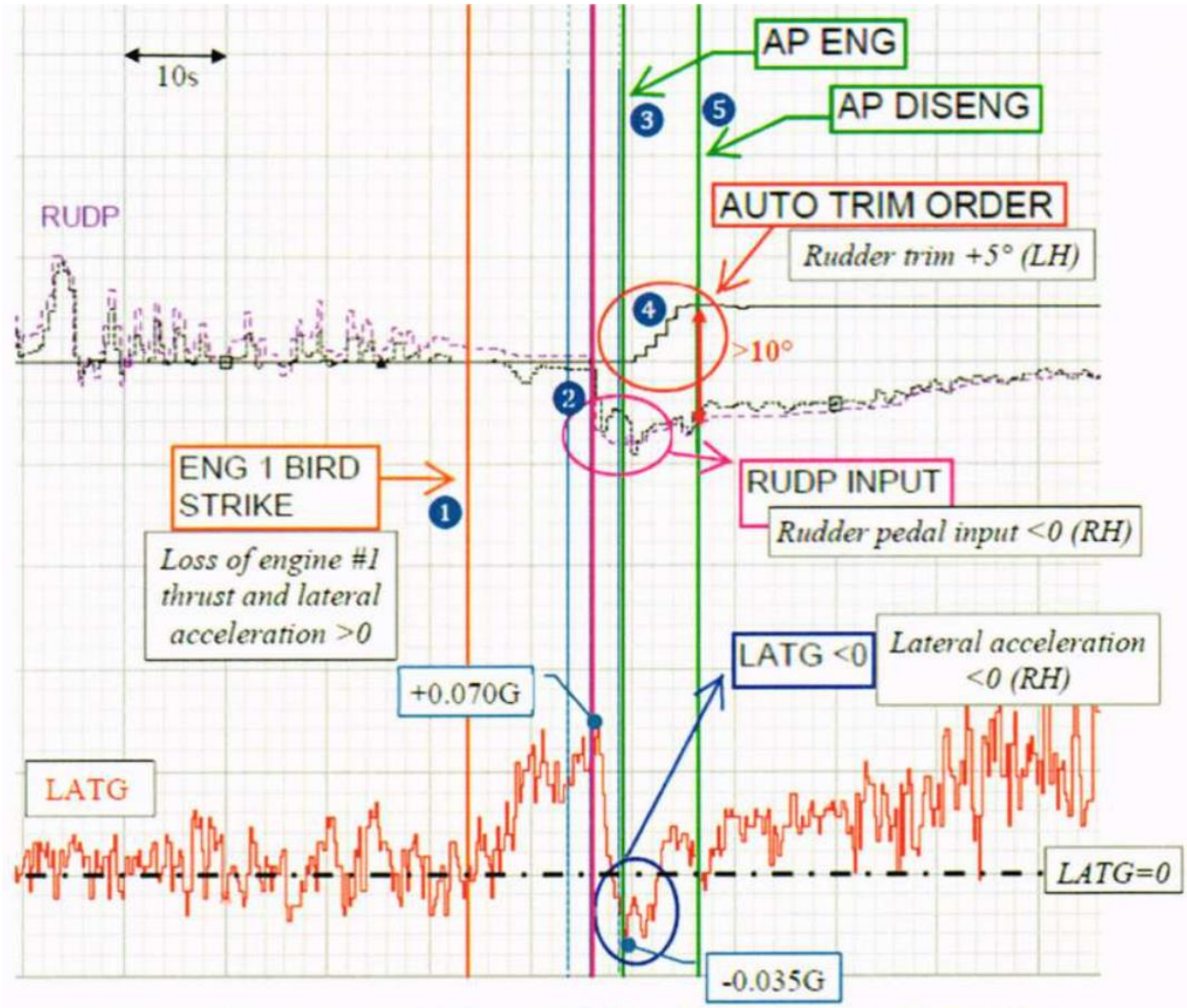



*Figure 86. Analysis of the reasons for the autopilot disengagement (the signs used on this diagram correspond to the conventions used by Airbus)*

(1) At 03:13:44, the thrust from engine No. 1 decreased following the bird strike. The airplane began to turn to the left (a decrease in heading), and a right sideslip and a lateral load (0.07 G) developed.

(2) At 03:13:57, the right pedal was deflected forward ≈8˚. The rudder trim was in the neutral position. As a result, the lateral load changed to the opposite direction (-0.035 G).

(3) At 03:13:58, the No. 1 autopilot engaged without trimming out the sustained pedal forces.

(4) At 03:14:00, the autopilot commanded 5˚ left rudder trim due to the negative lateral loading. The right pedal remained in the deflected position.

(5) At 03:14:05 the No. 1 autopilot disconnected because the pedal deflection differed from the rudder trim position by more than 10˚. This autopilot disengagement condition is described in the FCOM: *"In addition, in normal law with all protections available, the autopilot will disconnect when: …a rudder pedal deflection is more than 10˚ out of trim."*

**AP DISENGAGEMENT**

Ident.: DSC-22_30-30-00011818.0009001 / 04 NOV 13
**Applicable to: MSN 00735-00775, 01063, 01199, 01579, 02278, 02343-02376, 02707, 03107, 03385, 04728-09169**

AP1 or 2 disengages when:
- The flight crew presses the takeover pb on the sidestick, or
- The flight crew presses the corresponding AP pb on the FCU, or
- The flight crew pushes on the sidestick harder than a defined threshold, or moves on the rudder pedals beyond a defined threshold, or
- The flight crew moves the pitch trim wheel beyond a defined threshold, or
- The other AP is engaged, except when localizer/glideslope modes are armed or engaged, or when the rollout or go-around mode is engaged, or
- Both thrust levers are set above the MCT detent and the aircraft is on ground, or
- One of the engagement conditions is lost.

In addition, in normal law with all protections available, the AP will disengage when:
- High speed protection activates, or
- Angle-of-attack protection activates:
  - From the liftoff to 100 ft RA during the landing, when α prot +1 ° is reached, or
  - Below 100 ft RA during the landing, when α MAX is reached, or
- Pitch attitude exceeds 25 ° up, or 13 ° down, or bank angle exceeds 45 °, or
- A rudder pedal deflection is more than 10 ° out of trim.

*Figure 87. FCOM. Autopilot disengagement conditions*

Therefore, the autopilot disengagement occurred according to its nominal operating logic. The disengagement occurred due to the Captain's failure to follow the FCTM guidance concerning the need to trim out any rudder pedal forces before engaging the autopilot.

***Note:*** *FCTM A321. ABNORMAL AND EMERGENCY PROCEDURES. pp 13-26.*
*ENGINE FAILURE AFTER $V_1$*
*WHEN SAFELY AIRBORNE:*
*The use of the autopilot is STRONGLY recommended. Following an engine failure, the rudder should be trimmed out prior to autopilot engagement.*

The autopilot disengagement was involuntary (i.e. not because of crew commands); therefore, the master warning light illuminated, a red "AUTO FLT AP OFF" warning appeared on the ECAM (registered by the PFR at 03:14), and a continuous cavalry charge alarm sounded, which was heard on the CVR.

***Note:*** *FCOM. DSC-22 30-30 pp. 4-5. AIRCRAFT SYSTEMS. AUTO FLIGHT – AUTO FLIGHT GUIDANCE. AUTOPILOT (AP)*
*AP DISENGAGEMENT*
*In addition, in normal law with all protections available, the AP will disengage when:*

…
*- A rudder pedal deflection is more than 10˚ out of trim.*
*The standard manner for the flight crew to disengage the AP is to press the takeover PB on the sidestick.*
*When the AP is OFF, the associated pushbutton on the FCU goes off, and AP1 (or AP2) disappears from the FMA.*
*AP WARNINGS.*
*When the AP is disengaged, the system warns the flight crew:*
*- If the flight crew disengages it with the takeover PB on the sidestick, the warnings are temporary*
*- If the disengagement results from a failure, from the flight crew pushing the pushbutton on the FCU, or from a force on the sidestick, the visual and audio warnings are continual.*

| | | AP DISENGAGEMENT | |
|---|---|---|---|
| | | TAKEOVER pb on SIDESTICK | BY OTHER MEANS |
| CONSEQUENCE | MASTER WARNING light | Flashing red during 3 s maximum | Flashing red |
| | ECAM | AP OFF red message 9 s maximum | AUTO FLT AP OFF red warning |
| | AUDIO | Cavalry charge 0.5 s minimum 1.5 s maximum | Continuous cavalry charge 1.5 s minimum |
| | CLR pb on ECAM CONTROL PANEL | Extinguished | Illuminated |
| ACTION | MASTER WARNING light | - Extinguishes Master Warning light<br>- Erases ECAM warning<br>- Stops audio if pressed within 1.5 s | - Extinguishes Master Warning light<br>- Stops audio after 1.5 s |
| | CLR pb on ECAM CONTROL PANEL | No effect | - Extinguishes CLR pb<br>- Erases ECAM message<br>- Calls status |
| | TAKEOVER pb | - Extinguishes Master Warning light<br>- Erases ECAM warning<br>- Stops audio if pressed within 1.5 s | - Extinguishes Master Warning light<br>- Stops audio after 1.5 s |
| ECAM STATUS MESSAGE | | NO | YES |

### 2.2.3. Analysis of Engine Serviceability and Conformity to Certification Requirements After Bird Ingestion

According to the information presented in sections 1.16.2. and 1.16.3. of this report, the bird strike may have involved European herring gulls (Larus argentatus) and/or Caspian gulls (Larus cachinnans).

Mass of European herring gulls (Larus argentatus):

- Male: 909-1496 g (2.0-3.3 lbs)
- Female: 945-1385 g (2.10-3.05 lbs)

Mass of a Caspian gull:

- Male: 750-1193 g (1.65-2.63 lbs)
- Female: 680-1037 g (1.50-2.28 lbs)

This weight range spans two certification categories: medium birds from 1.5 to 2.5 lbs (0.68 to 1.13 kg), and large birds from 2.5 to 4.0 lbs (1.13 to 1.81 kg).

The aircraft was equipped with CFM-56-5B type engines, of which the left engine was the -5B3/P model and the right engine was the -5B3/3 model. Operational documents permit the installation of these two models on a single in-service aircraft.

According to information supplied by EASA, the -5B family of engines was developed from the -5A family and first underwent certification testing in 1992. Fig. 88 shows a timeline of the certification tests involving medium birds for the various models within this engine family. It should be noted that when certifying a new model, the scope of the certification tests can vary significantly depending on the differences from previous models.

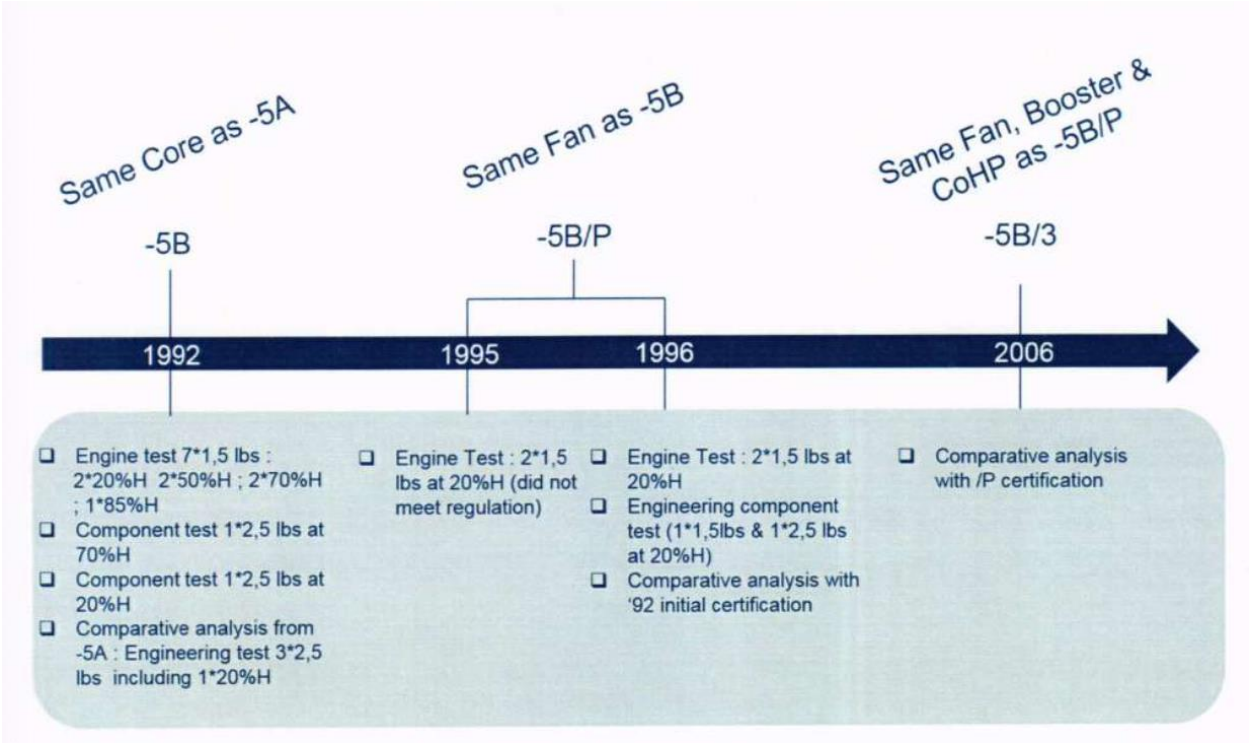



*Figure 88. Timeline of certification tests involving medium birds*

Based on the results of the research described in section 1.16.3. of this report, at least three birds were ingested into the left engine at three different locations, of which at least one bird was classified as "large", with a weight above 2.5 lbs (1.13 kg).

According to information supplied by EASA and the engine manufacturer, the -5B3/P model engine (left) was certified according to the 1992 requirements, which stated that the

engine should withstand the ingestion of one large bird.[58] According to the FAA and JAA certification requirements then in force (the two sets of requirements were identical), the ingestion of one bird with a weight of 4 lbs (1.81 kg) should not lead to:

- the ignition of a fire;
- uncontained engine failure involving ejection of high-energy projectiles;
- structural loads above the limits specified in paragraph 33.33(a) of the airworthiness standards;
- inability of the crew to shut down the engine.

The Commission's analysis showed that these provisions were met. Following bird ingestion, the engine continued to operate at a substantially reduced power level (see section 1.16.4.2. of this report). There was no evidence of fire, uncontained failure, or unacceptable structural loading. Most probably, the engine did not react to the crew's command to increase power because of mechanical damage resulting in a reduction to idle power. During the flight, the crew made no attempt to shut down the engine; after landing the engine was most probably shut down by the crew.

As established in section 1.16.3. of this report, the right engine (model -5B3/3) suffered an impact at about 85% span from at least one medium bird (more than 1.5 lbs), and there were some signs that this bird may have weighed more than 2.5 lbs, which would classify it as a large bird. An additional bird of undetermined size also impacted the inside of the nacelle.

According to information supplied by EASA and the engine manufacturer, the -5B3/3 model engine (right) was certified in 2006 (Fig. 88). No additional tests were conducted, so the results of the certification tests in 1992 and 1996 were applied. The requirements, evaluation criteria, and medium bird ingestion test results are shown in Fig. 89 and Fig. 90.

[58] The conditions on the accident flight were more severe, because in addition to the large bird, at least two more birds of undetermined size were also ingested.

**CFM56-5B (1992)**

**Requirements**

- FAA : 7 x 1.5 lbs birds including 2 in core
- JAA : 5 x 1.5 lbs birds including 1 in core
  - Criteria : 5 minutes operation, less than 25 % thrust
- JAA Special Condition :
  - 1 x 2.5 lbs bird in core
  - 1 x 2.5 lbs bird at 70 % Fan blade height
  - Criteria : 20 minutes run-on (back to terrain)

**Actual demonstration of compliance**

- Baseline regulation : Engine test
  - 7 x 1.5 lbs birds including 2 in core
  - Result of the test :
    - Stall recovery in about 1.8 sec
    - Thrust loss < 5 %, 5 minutes operation, EGT + 29 °C
- Special Condition : Combined component + engine tests
  - Engineering test on CFM56-5 engine
    - 3 x 2.5 lbs including 1 in core
      - Stall recovery in about 2 sec
      - Thrust loss 8 %, 5 minutes operation, EGT + 12 °C
  - Spin pit Component test : Fan blade
    - 1 x 2.5 lbs at 70 % height
    - Fan blade set installed into engine :
      - -12.8 % thrust (< 25 %)
  - Spin pit Component test : Fan blade + Booster IGV
    - 1 x 2.5 lbs at 20 % height (into core)
    - Booster IGV installed into engine :
      - No thrust change

**CFM56-5B/P(1996)**

**Requirements**

- FAA : 7 x 1.5 lbs birds including 2 in core
- JAA : 5 x 1.5 lbs birds
- JAA Special Condition :
  - 1 x 2.5 lbs bird in core
  - 1 x 2.5 lbs bird at 70 % Fan blade height

**Actual demonstration of compliance**

- Fan blades & bypass duct : Similarity
  - Rationale for similarity : same relevant hardware as CFM56-5B
- Core engine (new design on /P) : Engine test
  - Fan blade set from –5B engine test
    - Already hit by 7 x 1.5 birds
  - 2 x 1.5 lbs shot in core
    - More severe than 1 x 2.5 lbs
  - **Result of the test :**
    - Stall recovery in about 2.8 sec
    - Maintained 93 % thrust vs. Fan blades pre-ingestion condition (i.e. no thrust change from this test), EGT + 52 °C
    - 20 minute run-on completed

*Figure 89. Certification requirements for medium bird ingestion*

# Certification requirements – medium bird

*Synopsis of pass-fail criteria for medium bird ingestion certification tests of -5B (1992) and -5B/P (1996)*

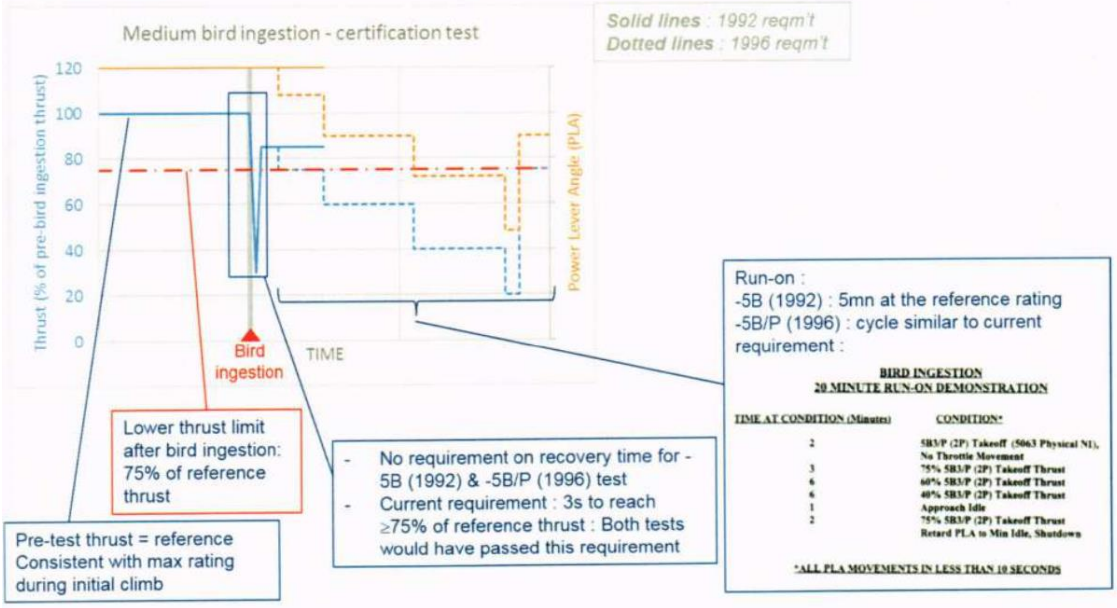



*Figure 90. Certification test criteria for medium bird ingestion*

Upon analyzing the conformity of the engine behavior during the accident flight to the certification requirements for ingesting a flock of medium birds, and the results of the certification testing, the Commission noted the following.

On the accident flight, the size of the instantaneous decrease in $N_1$ speed upon ingesting birds and the time to re-establish rotation were comparable to the values derived in testing, and in both cases this time was substantially less than three seconds, which is the current certification requirement, but was not required in 1992 or 1996.

One of the certification criteria is the amount of residual thrust that can be achieved after re-establishing rotation. According to the 1992 requirements, the loss of thrust in the absence of thrust lever movement should not exceed 25% of the thrust level at the moment of bird ingestion. Calculations showed (see section 1.16.4.2. of this report) that on the accident flight, the loss of thrust on the right engine after re-establishing rotation did not exceed 20%, in accordance with the certification requirements, until the selection of takeoff thrust by the crew.[59] The 1992 requirements also stated that the engine should continue producing these thrust levels for at least five minutes after rotation is re-established, in the absence of any thrust lever movement. On the accident flight, the engine only operated in this condition for 30 seconds, after which the crew increased thrust to the takeoff setting. As such, the Commission was unable to evaluate whether the behavior of the engine on the accident flight met the certification criteria regarding the length of continued operation.[60]

It should be noted that in the 1992 certification tests, the engine operating regime was not changed following bird ingestion, because there was no requirement to do so. On the accident flight, the right engine became unstable after TO/GA power was applied, and the average thrust value was 74.5% of TO/GA. The right engine was in the TO/GA regime for about a minute, until the aircraft landed.

At the same time, the damage to the first stage high pressure compressor during the accident flight (see section 1.16.3. of this report) was greater than that observed in certification testing.[61] In particular, no blade profile deformation was observed during the certification tests, while on the accident flight this was most probably the reason for the compressor stalls after thrust was increased to TO/GA. The Commission was unable to determine the reason for this different level of damage.

The certification criteria in 1996 increased the relative engine operating time after bird ingestion to 20 minutes and toughened the operating requirements (changes in operating regime were introduced according to the specified cyclogram, shown in Fig. 90). The criteria did not provide for a comparison between the increased engine operating regime and the operating regime prior to bird ingestion as was the case previously. For the reasons mentioned above, it was also not possible to evaluate whether the behavior of the right engine on the accident flight met the 1996 certification requirements.

---

[59] The Commission notes that the initial thrust value (before ingesting birds) on the accident flight was different from the value used in certification testing. In certification testing, the thrust was set to the maximum takeoff setting (a value of 100% on Fig. 90), at an altitude of 0 ft and an airspeed of 178 kt, meaning that the energy contained in the engine was greater.

[60] As was noted above, it was possible that on the accident flight, the right engine ingested a large bird. In that case, it would be possible to unambiguously confirm that the behavior of the right engine on the accident flight fully met the certification requirements.

[61] A description of the damage incurred during certification tests was provided to the Commission and included in the draft Final Report. This material was removed from the final draft of the report at the request of the engine manufacturer because it contained confidential material unsuitable for publication.

The Commission also notes that the operational documentation does not contain any limit on the speed with which the crew can move the thrust lever in the absence of any previous indication of a compressor stall. The recommendation to move the thrust lever slowly only applies if a compressor stall has already occurred and the crew is attempting to resolve the problem (see section 1.18.4. of this report). On the accident flight, the thrust levers were moved to TO/GA in less than a second, which, given the actual engine damage, could have contributed to compressor stall in the right engine. The certification tests used a much slower thrust lever movement (a time not exceeding 10 seconds).

### 2.3. Analysis of Flight Crew Training and Performance

#### 2.3.1. Analysis of Flight Crew Training

According to the available information, the Captain and the First Officer possessed valid pilot licenses with all required qualification marks. The crewmembers also possessed valid medical certificates.

The Captain had been released for independent flights as a an unassigned crewmember. According to the available documentation, the First Officer had no such approval.

According to the information provided by the airline, this crew pairing was created on 09/08/2019. No additional preliminary preparation for this pairing was conducted. At the moment of the accident, the crewmembers had flown 6 flights together.

According to the available information, the crewmembers had completed all required simulator training and checks (see section 1.5. of this report), during which they practiced engine failure after $V_1$, EGPWS, and emergency evacuation procedures.

During his simulator training, the Captain regularly practiced the engine failure after $V_1$ procedures. The two most recent training sessions before the accident took place in November 2018 and May 2019. The Commission determined that the simulator training scenario in the second half of 2018 involved an engine failure after $V_1$ with a takeoff mass close to the maximum permissible under the conditions. On the accident flight, the takeoff weight was ≈10% less than the permissible maximum.

***Note:*** *From the statements submitted by the Ural Airlines instructor pilot who conducted the Captain's simulator training in November 2018:*

- *"the simulator training was fully completed. All training topics were covered without any significant findings. All exercises were completed on the first attempt;*
- *gear retraction was accomplished at the proper time, with subsequent cross-check;*
- *maintenance of flight parameters (such as pitch angle, altitude, airspeed, and vertical speed) were accurately maintained in accordance with the FCTM and FOM;*
- *the autopilot was engaged at the proper time with subsequent cross-check;*
- *during the training and checks the Captain (I. O. [Last name]) demonstrated good knowledge, stable manual flying skills and auto-flight management, and satisfactory CRM skills (crew resource management, crew coordination, threat and error management)."*

*From the statements submitted by the Ural Airlines instructor pilot who conducted the Captain's simulator training in May 2019:*

- *"all topics were covered in accordance with the program. All exercises were completed on the first attempt, without any significant findings.*
- *the evaluation was conducted in accordance with the established simulator training methodology and in accordance with the evaluation norms established by part D of the FOM;*
- *there were no cases of failure to retract the gear, the gear was retracted at the proper time;*
- *the flight director arrows were followed with sufficient accuracy, and sideslip during an engine failure was countered quickly;*
- *flight parameters were accurately maintained in manual flight the overwhelming majority of the time during training, and the evaluation resulted in a grade of 5. Some insignificant deviations were rectified promptly and correctly;*
- *the autopilot was used in accordance with the recommendations of the FCTM and FCOM;*
- *no instances of autopilot engagement with an unbalanced aircraft were noticed;*
- *overall, the piloting techniques, crew coordination, crew resource management, knowledge, and use of aircraft systems corresponded to a grade of 5."*

A grade of "5," as the Captain received in his two most recent simulator training sessions, means, among other things, that in the instructor pilots' opinion, he accurately maintained the flight parameters during an engine failure after $V_1$ in accordance with the company's norms (see section 1.18.6. of this report).

Before the flight, the crew had sufficient rest in the comfortable conditions of a hotel. During the survey, the Captain stated: *"The rest conditions were completely comfortable, and the rest time was sufficient."* The First Officer stated: *"…the conditions were good. Nothing interfered with my rest."* At the same time, the Commission notes that the airline's time off schedule was not followed. The Captain's large amount of unused basic and additional time off while flying an intensive flight schedule away from his base could lead to the accumulation of chronic fatigue, reduced working ability, and decreased stress resistance.

***Note:*** *The Commission notes that during the investigations into a series of accidents and incidents in recent years involving large transport aircraft flying for Russian airlines, significant flight crew rest and duty time violations have been found, including delayed awarding of time off, which creates a substantial flight safety risk. In particular, these violations were found during the investigations into the crash of an Aeroflot Nord Boeing 737 in 2008, the crash of a Tatarstan Airlines Boeing 737 in 2013, and the crash of a Saratov Airlines An-148 in 2018, among others.*

### 2.3.2. Analysis of Flight Crew Actions Prior to the Bird Strike

The actions of the flight crew during the pre-flight preparation, engine start, and taxi to position corresponded to the standard operating procedures. All checklist items were completed

fully and at the proper times. The takeoff speeds, $V_1 = V_R = 166$ kt, and $V_2 = 168$ kt, were calculated correctly.

In particular, during the briefing in the cockpit, the Captain stated, "…In case of GO continue takeoff, no ECAM actions before one thousand … eight hundred except gear up, when engine secured push to level off…." The Captain also stated, "In case of an immediate return, we will land above the maximum landing weight…." According to the Captain's statement, he meant that the ECAM actions should not be carried out below 800 ft according to the QNH, which means 400 ft above the aerodrome elevation (the elevation of the airport is 123 m or 400 ft). This value corresponded to the provisions of the FCTM (see section 1.18.3. of this report) and to the Operator's standard operating procedures.

> ***Note:*** *URAL AIRLINES STANDARD OPERATING PROCEDURES, pp. 1-15:*
> *"In case of "GO," PF:*
> *continue TO, no action before 400 ft AGL except Gear Up;*
> *reaching 400 ft AGL, ECAM actions…."*

According to the Operator's FOM, "an adverse bird condition refers to the presence or appearance of birds along the path of the airplane (on the runway during the takeoff or landing roll or along the flight trajectory), which could lead to a collision." During certain times of year (including August), Ramenskoe Airport suffers from adverse conditions in terms of bird activity. Information related to this is laid out in the document entitled "Bird Safety Instructions for Ramenskoe Airport" (for more information see section 2.5. of this report). It should be noted that both before and after the accident, the Operator's airplanes were involved in bird strikes at this airport (see section 1.18.12. of this report).

Paragraph 8.1.0.8 of the FOM states that the pre-flight preparations must include, among other things, a study of *"the route (flight area) and its geographic, climatic, seasonal meteorological, and ornithological peculiarities…."* According to the available information, "ornithological" risks at this particular airport were not covered during the pre-flight preparations, nor was there any information about these risks at this airport in the Operator's FOM.[62] The crew themselves provided contradictory information about the presentation of bird risk information for this airport (see section 1.18.10. of this report).

The Commission notes that FAR part 128 does not contain any provisions associated with monitoring bird risks during the preparation or execution of flights. The FARFA[63] (Federal Aviation Regulations for Flights in the Airspace of the Russian Federation) contained paragraphs 205 and 206, which stated, among other things, that the commander of the aircraft must *"review official information about bird conditions before deciding to fly,"* and *"having received official information about adverse bird conditions,* [the commander] *must evaluate the feasibility of the flight. Takeoff under such conditions must be conducted with the lights on."* There are similar provisions in the Operator's FOM (paragraph 8.3.8.3.11).

However, the standard operating procedures do not specify any parameters according to which the crew should make their decision to fly. In particular, the procedures do not envision a situation in which the crew, having noticed birds at the airport, might request, for example, another runway inspection or taxi the aircraft along the runway to inspect it themselves. In the

[62] The FOM mentions "ornithological" risks for only one airport—Sochi.
[63] This document was in effect on the date of the accident, but was withdrawn by decree No. 1742 of the Government of the Russian Federation on 26/10/2020.

vast majority of situations, when in the takeoff position, the crew cannot physically discern the presence or absence of birds at any significant distance beyond the location of start of the takeoff roll. Crews are forced to trust the ground crews or else cancel the flight on the basis of risk.

> ***Note:*** *According to the caution after paragraph 8.3.0.12 of the Operator's FOM, the crew shall not take off in the presence of a large accumulation of birds that threatens the safety of the takeoff.*

All the factors listed above negatively influence a flight crew's "bird awareness," which should act as a defense mechanism, allowing a them to come to a decision in time to avoid a bird strike.

On the day of the accident, the bird situation at Ramenskoe Airport was "adverse." Before takeoff, the controller twice provided the crew with information about "isolated bird activity." However, the Commission established that the information about bird activity in the controller's transmission was included out of habit and did not always reflect the actual bird situation on the runway or the flight movement areas. Similar warnings are regularly included in the information given to flight crew, even at other airports in the Russian Federation. Such a situation leads the crew to become accustomed to the warnings, so that the message ceased to function as a warning, and becomes familiar background noise.

The existence of an adverse bird situation at Ramenskoe Airport at the time of the accident is supported by the flight crew's dialogue, which was captured by the cockpit microphone during the taxi for takeoff:

> *Captain: "There are, there are hardly any birds there, no?"*
> *FO: "Yeah no, hardly."*
> *Captain: "Hardly any? But some kind of flock is flying there."*
> *FO: "Ah, well, there something's flying."*
> *Captain: "No, I mean on the runway."*
> *FO: "No, there are hardly any on the runway."*
> *Captain: "That's it, let's go. We're ready for takeoff."*

According to the Captain's statement, he saw birds while taxiing on taxiway B7 (the taxiway layout is shown in Fig. 29): *"The first time I saw birds was while I was turning from the main taxiway onto B7; I didn't see where they set down, but I did see them when they took off, after increasing power, there was a flock of birds."* The First Officer confirmed that birds were seen at this point. According to the flight crew's explanations, before the start of the takeoff they waited while the birds flew away, which does not fully correspond to the established facts. According to the FDR recording, less than 10 seconds passed between the end of the taxi into position and the start of the takeoff. The pilots did not request assistance from ATC in searching for birds.

According to the crew's statements, the takeoff was conducted with the lights on. Judging by the cockpit conversations, during the start of the takeoff roll (at a speed of around 60 knots), the Captain again noticed the presence of birds: *"Come on, [unintelligible];" "Fly past, bird,*

*fuck."*[64] The Captain uttered these phrases in between standard callouts, indicating that the observation of birds most probably caused significant alarm.

The Commission observed another noteworthy moment during the takeoff roll. Five seconds after the First Officer made the standard callout "One hundred knots," and the Captain's reply, "Checked," at 03:13:26.8 the First Officer exclaimed, *"Fucking hell,*[65] *fuck."*[66] No other utterances by the flight crew were recorded at this stage of the takeoff roll, and after a further ≈10 s the First Officer called out *"$V_1$"* in accordance with the SOP.

> ***Note:*** *From the transcript of the First Officer's interview:*
>
> *"Q: The standard callouts are made – "One hundred knots," "checked," a pause, then "Fucking hell, fuck," then another pause, then "$V_1$, rotate." What prompted the use of foul language? What did you see? Maybe something with the airplane? What could have prompted such a reaction from you? What disturbed or startled you?"*
>
> *A: Well, I don't remember actually, it might have been a reaction to the Captain's comments. The Captain said "Fly away, bird, fly away." And I was concentrating on the instruments, and then there was something like, "oh, there are birds."*
>
> *Q: So it was a reaction to the birds?*
>
> *A: Well yes, in some manner. He said that he saw bird flying past, somewhere up high.*
>
> *Q: And did you see it yourself?*
>
> *A: Most of my attention was focused on the instruments, on the speed, on the engine parameters. I also glanced briefly at the airspace, at the centerline, at the takeoff roll. I didn't specifically notice anything like "oh, there are birds."*

The Commission analyzed video clips taken by passengers during the takeoff roll. In the video clips taken at this point in the takeoff, when the aircraft was abeam the Ramenskoe control tower (airspeed ≈140 kt), flocks of birds could be seen taking off from the right (Fig. 91).

---

[64] Henceforth, the Commission includes the flight crew's quotations without redacting profanity, because in this case it characterizes their psychological condition.

[65] Translator's note: The Russian expression used was "Ёбанный в рот" ("Yobannyi v rot"), literally "Fucked in the mouth.") The expression "Yobannyi v rot" is semantically similar to "Fucking hell."

[66] The analysis of the crew conversations confirms that under normal circumstances, the First Officer does not use profanity in this manner.

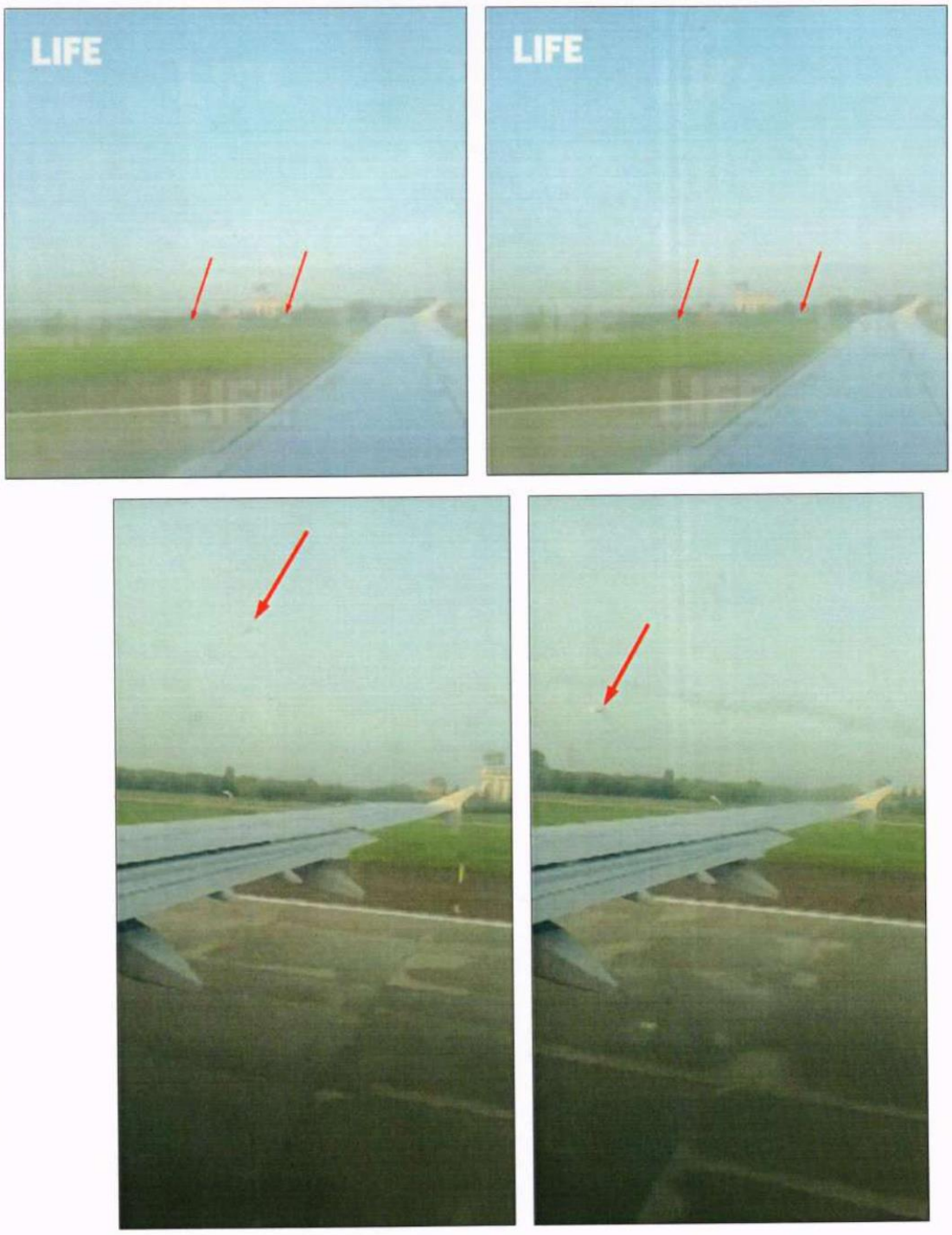



*Figure 91. The moment that birds (indicated with arrows) appeared to the right of the aircraft during the takeoff.*[67]

[67] Translator's note: The images come from a low quality scan that lacks sufficient resolution identify birds in the photos. This does not mean that the birds are not visible in the original photographs.

The Commission could not exclude the possibility that the First Officer's emotional reaction was prompted by the observation of a flock of birds at that precise moment. The airspeed at that time would have permitted the crew to safely reject the takeoff.

***Note:*** *The SOPs inform the crew that below a speed of 100 kt, the Captain can decide to reject the takeoff, depending on the circumstances. However, rejecting the takeoff at a speed above 100 kt "is a more serious matter." Nevertheless, under the circumstances of the accident flight, given the available runway length, the Commission believes that a rejected takeoff would have been safe at any point prior to reaching* $V_1$.

The callouts upon reaching decision speed and rotation speed were issued by the First Officer at the proper time (these two speed values were identical). The Captain did not make any comments regarding the rejection or continuation of the takeoff (such a callout is not required by the Operator's SOPs nor by the SOPs of the manufacturer), and he quickly raised the nose and established the takeoff pitch angle.

The SOPs recommend a rotation rate of 3˚/s up to an initial pitch angle of 15˚ (with two working engines). On the accident flight, the rotation was prolonged, with a rotation rate less than 1.5˚/s. The aircraft lifted off the runway at a pitch angle of 7˚ and a speed of 180 kt, which is considerably more than the calculated $V_2$ takeoff safety speed (167 kt).

***Note:*** *The Commission notes that the criteria for evaluating the quality of a takeoff, according to the Operator's FOM (see section 1.18.6. of this report), are partially outdated and do not correspond to actual takeoff practices. With these criteria in mind, an instructor pilot should evaluate, among other things, adherence to the prescribed liftoff speed. However, this speed is not included in the takeoff calculations. The aircraft manufacturer commented that in its opinion, rather than evaluating the liftoff speed, which is not calculated, the instructor should evaluate adherence to the prescribed rotation rate.*

### 2.3.3. Analysis of Flight Crew Actions While Enacting the Engine Failure After $V_1$ Procedure

The bird strike occurred immediately after liftoff from the runway. According to the CVR recording, after the collision the crew did not call out or discuss the engine parameters. Therefore, the Commission could not unambiguously determine the moment when the crewmembers decided that an engine or engines had failed and that they would need to apply the engine failure after $V_1$ procedure, or whether they identified the nature of the failure (partial or complete, with or without damage). The only thing that can be said for certain is that by 03:13:54 (9 seconds after the bird strike), when the Captain deflected the right rudder pedal to counter the yawing moment, he should have had a clear impression of the developing thrust asymmetry. The Captain first used the words "engine failure" only at 03:14:31 while making a report to the controller.

The FCTM (see section 1.18.2. of this report) describes possible reasons for an engine failure, as well as indications that the crew can use to recognize a failure and determine its nature. Based on these descriptions and the actual engine parameters, the crew could have

identified the existence of a failure with engine damage[68] (but without shutdown) due to the bird strike during the earliest stage of the flight. The problem with the right engine (in the form of an insignificant decrease in $N_1$) probably was not noticed by the crew during the initial stage (prior to the application of TO/GA power). The Commission notes that during the course of the flight, the crew was not able to determine the total remaining thrust or evaluate the damage to the engines.

As such, among the scenarios described in the operating manuals, the actual situation most closely resembled an engine failure after $V_1$ following an engine failure above $V_1$. The crew's decision to continue the takeoff was well-founded.[69]

***Note:*** *From the Captain's interview transcript:*

*"Q: Did you conduct any risk analysis of possible course of action, including rejecting the takeoff at a speed above $V_1$, given the large runway length?*
*A: I did not consider any other possibilities, including rejecting the takeoff above $V_1$; this is not considered in any documentation."*

The most important aspects of an engine failure after $V_1$ are included in the AFM.

***Note:*** *AFM. ABN-OEI-TO pg. 2/4. ENGINE FAILURE BETWEEN $V_1$ AND $V_2$ Once airborne and with positive rate of climb:*
*Retract landing gear.*
*Maintain airspeed not below $V_2$.*
*SRS guidance should be followed when FD pitch order is established,*
*Use rudder to prevent yaw. Shortly after lift off, the ß target will appear. Adjust rudder position to zero the ß target. Control heading conventionally with bank keeping ß target zeroed with the rudder.*

A more detailed engine failure after $V_1$ procedure, including the underlying philosophy behind the actions, is included in the FCTM (see section 1.18.3. of this report). The Operator's SOPs include a link to this section of the FCTM.

Flight crew actions during an engine failure after $V_1$ are designed to minimize drag on the airplane and maintain a safe airspeed with reduced thrust. Generally, the procedure can be divided into the following basic steps:

- quick gear retraction after achieving a positive climb rate (this significantly reduces drag);
- airspeed maintained no lower than $V_2$ by following the flight director pitch command bars (guaranteeing flight at an angle of attack with an adequate stall margin and with optimal induced drag);
- deflection of the pedals and centering of the beta target (minimizing the deflection of the control surfaces and guaranteeing minimal drag amid changing flight parameters);
- use of the autopilot (increasing the precision with which flight parameters are maintained and decreasing crew workload). Before engaging the autopilot, it is important to trim the aircraft in yaw (remove pedal force).

[68] In this context, "failure" means the inability of the engine to provide the commanded thrust. Possible reasons for this are considered in section 1.16.3. of this report.
[69] See section 1.1.1. of this report.

It should be noted that all other actions (except silencing any aural alarms) should be carried out after stabilizing the aircraft on a safe trajectory and reaching an altitude of at least 400 feet above the runway elevation.

Three seconds after the bird strike, the First Officer called out, *"Climb,"*[70] and not *"Positive climb,"* as called for in the SOPs.

***Note:*** *Ural Airlines Standard Operating Procedures, pg. 3-29*
*WHEN POSITIVE CLIMB*
"POSITIVE CLIMB" …….. ANNOUNCE PM
"GEAR UP" ……... ORDER PF

The Captain never reacted with the command to raise the gear (in his survey, the Captain indicated that he didn't hear the First Officer's callout). The First Officer did not call the Captain's attention to his omission of this item, and the crew never returned to the topic of raising the gear at any point during the flight. The gear remained in the extended position practically until touchdown.

***Note:*** *From the First Officer's interview transcript:*
*"Q: You called out "Climb," but this wasn't followed by an order from the commander to raise the gear. What does the SOP say? Are you required to repeat the callout, draw attention to it?*
*A: If the commander doesn't do something, and you notice some kind of mistake or problem, you should always tell the commander.*
*Q: So why didn't you tell him this time?*
*A: At that moment my main attention was focused on the failure and we just forgot."*

Therefore, the crew omitted the step of raising the gear. The omission of this type of step, which is accomplished "automatically" on every flight, indicates that at this stage of the flight, both crewmembers probably entered a suboptimal emotional state,[71] in which their situational awareness was critically narrowed. This most probably occurred because of the sharp jump in emotional stress after the bird strike; that is, the crew began to lose psychological fitness.[72]

***Note:*** *As was described in section 1.16.4.3. of this report, during the actual, worsening conditions of the accident flight, given the remaining thrust it was critically important that the gear be raised in order to continue gaining altitude without losing speed. With the gear extended, a safe climb was impossible, meaning that any further flight crew actions (with the gear still in the extended position) would be ineffective from the point of view of continuing the flight. At the same time, the crew did not have information about the exact amount of thrust remaining. The*

[70] This was the first crewmember statement recorded by the CVR after the bird strike.
[71] Because it was not possible to evaluate the magnitude of the increase in the crew's emotional stress level, the term "suboptimal emotional state" is used hereinafter.
[72] A loss of effectiveness and directedness of cognitive actions.

*Commission considered all further crew actions during the initial phase of the flight (until disconnection of the autopilot) to be in accordance with the standard procedures for an engine failure after $V_1$ per the FCTM.*

The bird strike (the combination of the sight of a large number of flying birds and the numerous impact sounds) probably subjected the crew to the "surprise effect."[73] This "surprise effect" could have been intensified by the sensation of greater than normal vibration which appeared due to the damage to the engine fans.

***Note:*** *FAA Advisory Circular AC120-111 revision 1 defines a "surprise" as an unexpected event that violates a pilot's expectations and can affect the mental process used to respond to the event.*

The next phrase registered on the CVR, two seconds after the previous (at 03:13:50), was the First Officer's callout concerning the appearance of the "thrust reverser unlocked" ECAM message. The Captain confirmed that this warning had activated.

By this point the Captain most likely had not yet identified the failure of the left engine (thrust asymmetry), so he had not deflected the pedals to counter the yaw and maintain the beta target. In his interview, the Captain described impression of this moment: *"I identified the bird strike by the multiple impacts and the sound of the engines. Almost immediately, the ENGINE 1 REV UNLOCKED warning came on; the flight director appeared and I flew by the flight director. I gained altitude. Thrust from the left engine decreased; the Beta target appeared, and I used the right pedal to clean up the slip and balance the plane…"*

The Commission notes that the Captain actually followed the flight director pitch command arrows only during the first seconds after the failure. Immediately after the failure, the pitch angle was stabilized at a value of around 8.5˚. The position of the flight director arrows at this stage progressively decreased until it reached the opposite value (see Fig. 35). Over the next several seconds, the Captain increased the pitch angle, first to 10˚ and then to 12.7˚, despite the flight director's command to pitch down. As a result the flight director indications increased to 6.7˚ in the pitch down direction. The Captain's actions did not correspond to the indications of the flight director arrows.

***Note:*** *On the flight data recording, a positive flight director arrow deflection indicates a command to pull up, and a negative value means to push down. This value determines the desired magnitude of the pitch change, calculated with reference to the actual pitch angle. For example, if the actual pitch angle is 5˚ nose up, and the deflection of the flight director arrow is -3˚, then after following the flight director command, the pitch angle will be 2˚ nose up and the flight director arrow will be at 0˚.*

The fact that the Captain pitched up to ≈12.5˚ while simultaneously deflecting the right rudder pedal to counter the yawing moment suggests that at that moment he probably fully recognized that that the left engine had failed, and began to act according to the established procedure. A pitch angle of 12.5˚ is listed in the FCTM as an initial value that should be

[73] In their interviews, both crewmembers indicated that they had never experienced a "serious" situation or emergency in actual flight, nor had they ever been involved in a bird strike.

achieved after liftoff during an engine failure after $V_1$. The Commission notes that this FCTM provision relates specifically to the moment of liftoff from the runway. The observed increase in pitch angle 10 seconds after liftoff, with decreasing airspeed and the flight director arrow indicating "nose down," suggests that the Captain had lost situational awareness and was acting according to ingrained instincts, albeit with a significant lag and without an in-depth analysis of the flight parameters (including ignoring the position of the flight director pitch command arrow).

After deflecting the right rudder pedal, the Captain engaged the autopilot and informed the First Officer, who confirmed its engagement. The engagement of the autopilot corresponded to the FCTM provisions for an engine failure after $V_1$. At the same time, the Captain did not reduce the force applied to the pedal before engaging the autopilot, which caused the autopilot to disconnect after about 6 seconds (see section 2.2.2. of this report and further in this section). The FCTM informs of the need to trim out forces in the yaw channel before engaging the autopilot. According to the instructors who conducted the Captain's simulator training, he had no problems with trimming during an engine failure after $V_1$. Once again, the Captain's failure to trim out the forces probably had to do with his suboptimal emotional state.

> ***Note:*** *As was noted in section 2.1. of this report, the Captain engaged the autopilot without centering the flight director pitch command arrow. This does not correspond to the FCTM provisions. According to airline representatives, flight crew training stresses the importance of centering the flight director arrows before engaging the autopilot. The failure to complete this action also highlights the Captain's suboptimal emotional state, in which he probably sought instinctively to engage the autopilot "as fast as possible."*

Immediately after engaging the autopilot, the Captain gave the "ECAM action" command to the First Officer. During the pre-flight briefing the Captain had specified that the ECAM procedures should be completed only after reaching a height of 400 feet above the runway level. The maximum height above the runway achieved during the accident flight was less than 300 feet. As such, the Captain's command contradicted his own statements before the flight.

During his interview, the Captain explained that the reason he gave the "ECAM actions" command was because, *"a reverser may have deployed, so I thought it was critical to carry out the actions immediately."* The Commission notes that the "ENG 1(2) REVERSE UNLOCKED" message is one of five "caution"-level messages for which the FCOM (PR-AEP-MISC pp. 19/34) recommends considering a rejected takeoff should they activate at a speed above 100 kt but below $V_1$. Crews regularly perform this maneuver in training. An emotionally stressful situation can cause a "negative transfer" of learned skills from the takeoff roll onto the initial climb phase after liftoff—that is, the phase of flight in which, according to the FCTM, maintenance of the proper aircraft trajectory by following the speed reference system commands is the number one priority.

The Commission believes that after engaging the autopilot, the Captain probably felt that he had dealt with the initial actions for an engine failure after $V_1$ and that he could now complete the ECAM actions. At the same time, the Captain's evaluation of the situation did not correspond to reality. The aircraft at that moment was not established on a safe climb trajectory, its airspeed had fallen to $V_2$ and was continuing to decrease (a negative speed trend was indicated on the PFD), and the flight director pitch command arrows were not followed. These facts again

demonstrate the Captain's lack of a complete picture of the flight due to his elevated emotional stress.

After the Captain's command, the First Officer read off the name of the ECAM procedure and the first item of the procedure: *"Engine one reverse unlocked, thrust lever one IDLE."* Almost simultaneous with the end of the First Officer's statement, the autopilot disengaged, triggering an aural warning (see section 2.2.2. of this report). Because the autopilot disconnection occurred involuntarily, a red "AUTO FLT AP OFF" message would have appeared on the ECAM. Because the "ENG 1 REVERSE UNLOCKED" message already on the screen was a yellow message, the autopilot disconnect message would have appeared at the top of the screen (above the existing messages).

The aural autopilot disconnect warning continued almost until the end of the flight; the crew did not silence it. At this stage the crew did not discuss the autopilot disconnection, and they did not make any attempts to understand why it had disconnected or to reengage it. At the same time, the fact that the Captain started to make inputs using his side stick practically as soon as the warning activated indicates that he was aware the autopilot had disengaged.

> ***Note:*** *The autopilot disconnect warning is loud and alarming, creating a stressful auditory environment in the cockpit. Later in the flight, this effect intensified due to the activation of the EGPWS and the sounds produced by abnormal operation of the right engine in the TOGA regime. These aural warnings probably added to the crew's emotional stress. In his interview, the Captain stated that he heard the warning but did not silence it because the sound did not bother him. The Commission notes that this explanation is illogical. This warning can be silenced with the press of a single button, located on the side stick, which does not demand any diversion of attention from the task of flying the airplane and should be accomplished automatically by an experienced pilot (if the pilot hears and comprehends the warning). Due to his suboptimal emotion state, if the Captain even heard the warning, then he probably did not comprehend it. Similar examples have been encountered in previous investigations conducted by the MAK Commission (see, for example, https://mak-iac.org/upload/iblock/ba0/report_vq-bbn.pdf).*

Due to the activation of the autopilot disconnect warning, the First Officer called out, "Confirm thrust?" The Captain answered, "Check," although he had not moved the left thrust lever to the idle position. In his interview, the Captain stated that in his recollection, he had decreased the thrust lever position, but this was not confirmed by the recorded flight data. This fact again underscores the flight crew's critical narrowing of perception. The crew did not return to the ECAM actions.

At 03:14:10, the EGPWS "DON'T SINK" warning activated. At this stage of the takeoff, this warning activates if the aircraft's height decreases by a certain amount, depending on the aircraft's current height, and if the aircraft is not in the landing configuration. According to the FCOM, when this warning activates, the crew must correct the aircraft's trajectory (using pitch and thrust) until the warning stops. By deflecting his side stick nose up, the Captain stopped the descent and silenced the warning (which was active for 3 seconds). At 03:14:19, the warning activated again. This time, in addition to pulling back on the side stick, the Captain also moved both thrust levers into the takeoff regime. This time, the warning continued for 5 seconds.

Therefore, the Captain's actions corresponded to the FCOM provisions for this type of warning. The Captain may have heard the warning and reacted instinctively during the flight, but did not retain this fact in his memory due to elevated emotional stress.

> ***Note:*** *After both thrust levers were placed in the TO/GA regime, the right engine began to show obvious signs of a compressor stall, with the corresponding sound effects. Among themselves, the crew did not discuss the reasons for the right engine's abnormal operation nor any possible corrective actions. The actions required of the crew in this situation are described in the QRH (see section 1.18.4. of this report).*

Between the two "DON'T SINK" warnings, the Captain attempted to call the controller, transmitting, *"Pan-pan, pan-pan, pan-pan, Sverdlovsk…"* However, he did not finish the sentence. According to the Captain's explanation, he tried to make the report himself, as he was not sure of the First Officer's emotional state, so he took the responsibility upon himself. In this case the Commission notes two immediate potential risk factors. Firstly, this is a clear violation of basic CRM principles, especially in light of the lack of time and very high crew workload. And secondly, this was a violation of the principle of "aviate, navigate, communicate." The aircraft was not established on a safe climb trajectory, its speed was already less than $V_2$ and was still decreasing, the autopilot had disconnected involuntarily for reasons unknown to the crew, and the autopilot disconnect warning was still sounding.

> ***Note:*** *According to SOPs, when carrying out actions according to the ECAM or QRH, the flying pilot is responsible for conducting radio calls. However, at this point, and throughout the remainder of the flight, the ECAM procedure that was started earlier had effectively been abandoned, although there was no formal command to end it or any report about its completion. Most likely, the rapidly changing situation caused the crew to "forget" about this procedure and ignore its completion. Because of this, and because of the Captain's above statement, the Commission believes that at this stage of the flight, a standard distribution of responsibilities, in which the non-flying pilot conducts radio calls, would have been most optimal.*

The Captain's further actions were aimed primarily at maintaining altitude (preventing descent). With a greatly narrowed perception of the flight, altitude (or the lack of a negative vertical speed) became the sole (or dominant) parameter on which the Captain was focused.

> ***Note:*** *According to the FDR recording, at this stage of the flight, the position of the flight director pitch arrow was around 0° with insignificant decreasing oscillations. This fact may indicate that the Captain was trying to maintain the flight director commands. On the other hand, given that the flight was maintaining altitude, and given the flight director pitch arrow's working logic at this stage (maintaining a vertical speed of 120 ft/min), the flight director arrow would be located practically in the center of the instrument.*

Attempts to maintain altitude with insufficient thrust led to further loss of airspeed. The Captain most likely understood that they needed to control their speed. At 03:14:29, he gave the First Officer the command, *"Autopilot off. Watch speed."* However, the First Officer never called out their airspeed.

The First Officer was in a state of confusion (most likely due to his elevated excitability; see section 1.16.6. of this report). While the CVR captured few callouts from the First Officer of any kind, even those at variance from the standard phraseology, he did utter numerous expressions of confusion (at 03:13:55: "*Motherfucker. So…;"* at 03:14:19: *"So, ah…;"* at 03:14:30: *"So…;"* and at 03:14:40: *"Um…"*). In general, the First Officer did not fulfil the duties of the pilot monitoring. As the situation developed, he made only a single callout—*"Altitude, altitude"* (at 03:14:58)—despite significant deviations from the normal flight parameters. Therefore, altitude was the parameter that he had prioritized as well.

The large number of involuntary side stick inputs in the pitch and roll channels (Fig. 92) also testify to the First Officer's stressed condition. Investigations of aviation accidents and incidents have shown that when a pilot is in a suboptimal emotional state and is losing the ability to holistically perceive the situation, they will often start making involuntary or reflexive control inputs due to the "startle effect." In this case, the First Officer's control inputs were insignificant in amplitude, did not lead to a DUAL INPUT warning,[74] and did not interfere with the Captain's flying.

> ***Note:*** *FAA Advisory Circular AC120-111 Revision 1 defines the "startle effect" as "an uncontrollable, automatic muscle reflex, raised heart rate, blood pressure, etc., elicited by exposure to a sudden, intense event that violates a pilot's expectations."*

[74] According to the manufacturer, this warning activates in the event of simultaneous side stick inputs greater than 2˚ in pitch or roll for at least 0.5 s.

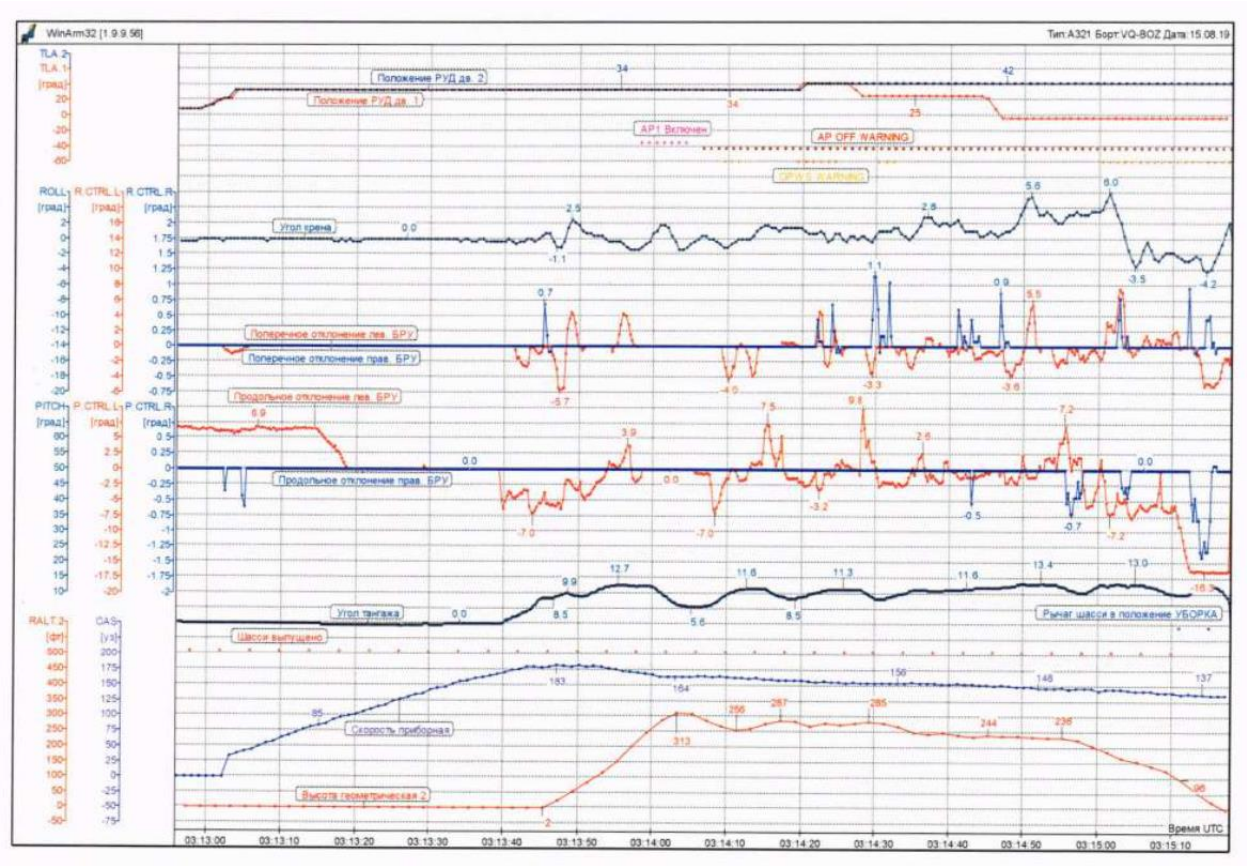



*Figure 92. Comparison of the Captain's and First Officer's side stick positions (the scales for the two pilots' side sticks are different in order to improve readability). Roll inputs are shown in the third line graph from top, and pitch inputs in the fourth line graph from top. The Captain's inputs are in orange and the First Officer's inputs are in blue.*

At 03:14:31, after a call from the air traffic controller, the Captain reported an engine failure and declared "PAN-PAN." The Captain then ordered the First Officer to request a turn back to the runway, which the First Officer did. At this point the Captain was maintaining an altitude of around 240 ft, while the indicated airspeed had fallen to 150 kt and was continuing to decrease. Shortly thereafter, the critical angle of attack and stall protection system activated. Under such conditions, an orbit and return to the airport was practically impossible. However, the Captain considered only this option, and not the possibility of a forced landing.

Another characteristic of the crew's tunnel vision[75] was the pedal deflection. After recognizing the engine failure (asymmetric thrust), the Captain deflected the pedals to a value practically corresponding to that required to center the beta target indicator, and maintained them in this position for around five seconds. The calculated pedal force was 20-25 kg (see section 1.16.4.1. of this report). Over the course of the next minute, however, the pedal deflection steadily decreased (as a consequence of a corresponding decrease in pedal force). The Captain clearly did not notice, even though the difference between the actual and commanded sideslip angles became quite significant (≈7.5˚). According to the instructors who oversaw the Captain's simulator training, he did not experience any difficulty maintaining the beta target.

[75] Tunnel vision is a focus on a part or small part of one's reality at the expense of all else.

This phenomenon, the loss of reaction to a force, is well known in psychology (including pilot psychology). The forces on the pedals during the initial reaction to the engine failure were sufficiently noticeable, albeit not "critical," as defined by the certification requirements (the maximum allowable short period pedal force is 150 lbs (≈68 kg), according to Far Part 25 paragraph 25.143[76]). At the same time, maintaining these forces for an extended period of time (if the pilot mistakenly fails to trim them out, as occurred on the accident flight) requires the application of physical force, but also a constant awareness of the fact that this must be done.[77]

> ***Note:*** *According to the explanation contained in EASA CS-25 AMC 25.143(d) and in FAA AC 25-7C (Section 3: Controllability and Maneuverability, paragraph 20. General §25.143), the short period pedal force refers to the forces that arise, among other times, immediately after the controls are deflected from their normal positions in order to react to a failure. The peak force values while reacting to a failure are not regulated. It is assumed that after reacting to the failure, the pilot will trim out the forces as fast as practicable. Continuous forces are considered to be those that cannot be trimmed out using the trim system or any other method. Therefore, on the accident flight, the actual continuous forces exceeded the maximum values established in the aviation regulations due to the Captain's failure to trim out the pedal forces.*

With their field of awareness narrowed (loss of situational awareness, appearance of tunnel vision), the pilot focuses on a limited selection of parameters, sometimes as few as one or two. On the accident flight, it was clear that the dominant parameter was altitude. Under such conditions, the pilot's legs (or any other part of the body involved in making control inputs) can "stick" to the controls, and the resultant forces will be reflexively countered (as in the prolongation of an action taken earlier). If the forces are comparatively small and/or the development of the situation ends quickly, then the controls may be maintained in a deflected position even if this is no longer necessary or is negatively affecting the safety of the flight (see, for example, the findings of the investigation into the crash of the Il-86 RA-86060 on 28/07/2002 at Sheremetyevo Airport, or the crash of the Boeing 737NG A6-FDN on 19/03/2016 at Rostov-on-Don Airport, concerning the holding down of the stabilizer trim switch). If the forces are large or the development of events lasts a relatively long time (as in this case), then, in the absence of constant awareness of the need to apply a force, the force will weaken with time and the controls will return to the neutral position. This is what happened with the Captain in this case. Despite indications of a substantial difference between the desired and actual sideslip angles, the pedals smoothly moved toward the neutral position over the course of approximately one minute.

Therefore, from the very beginning of the event, the actions of the crew, especially the Captain, were characterized by disorganization, inconsistency, and chaos, indicating partial psychological incapacitation. Although it did not reduce them to a psychological stupor, the situation exceeded the psycho-emotional capabilities of the crewmembers. In fact, during the first phase of the engine failure after $V_1$ (up to the engagement of the autopilot), the crew did not perform a single one of the actions called for in the engine failure after $V_1$ procedure (or performed them out of order): in particular, they did not raise the landing gear, they ignored the

[76] An analogous definition is included in the EASA and FAA aviation regulations.
[77] This same regulation states that the maximum sustained pedal force shall not exceed 20 lbs or 9 kg.

flight director pitch command arrows, they did not center the beta target, and they did not trim out the rudder pedal forces before engaging the autopilot.

Thereafter, they did not keep the airspeed within the required limits (not lower than $V_2$), while they initiated, but did not complete, various other actions that were not of primary importance in the developing situation. The crew's teamwork and CRM were unsatisfactory.

After familiarizing themselves with the flight recorder data, the flight crew members evaluated their own condition as follows:

***Note:*** *1. From the Captain's interview transcript:*

*"Q: How would you subjectively evaluate your readiness for a rejected takeoff (at any stage) and a landing outside the aerodrome (on land or water)?*
*A: Of course I was ready. You always keep it on your mind. When you take off, it's tensed like a spring. Nobody was driving us, we flew on schedule. I think every pilot is running it through their head, what he would do. In theory everyone is thinking about this.*
*Q: How would you, post factum, evaluate your readiness for the situation which appeared during this flight? Did it exceed your psychological and physiological capabilities?*
*A: I don't think there was any "stupor;" I kept acting until the end. Mistakes were made, yes, we didn't raise the gear; I didn't trim out the sideslip, which caused the spoilers to deploy; the decrease in speed, the increase in pitch angle. But I think that my psycho-emotional limits were not exceeded, because I tried until the end, I understood what was happening, but I didn't comprehend in those moments the things we were talking about. And after the landing, after we stopped, I still didn't fall into a stupor; I understood what was going on."*
*2. From the First Officer's interview transcript:*
*"Q: Out of everything described above, can you now, post factum, tell me whether your simulator training on engine failures after $V_1$, whether those methods that were used were sufficient, or should something be improved? Should we allow more difficult situations, to make the pilots stressed before giving the exercise, what do you think? Were you ready for the situation that actually happened in flight? Or did you lose your nerve, or was there some kind of distraction?*
*A: I think it was tunnel vision.*
*Q: To speak crudely, did the actual situation exceed your ability to perceive the whole flight?*
*A: Yes, and time was compressed, it happened immediately after takeoff, literally. So I got tunnel vision.*
*Q: In general, were the simulator training scenarios on engine failures after $V_1$ sufficient, or would it have been better if there was more training?*
*A: I think the simulator scenarios were good enough in principle. The situation itself was unique.*
*Q: In what way?*
*A: Because real life is nothing like the simulator."*

Considering that the crew demonstrated good theoretical knowledge of the relevant topics during post-crash interviews, that all required training and checks had been carried out on the day of the accident, and that they had received only positive evaluations from their instructors, the pilots' disorganized actions (partial psychological incapacitation) could be associated with their own psychological peculiarities (see section 1.16.6. of this report). The crew faced an abnormal situation involving a need to carry out the engine failure after $V_1$ procedure while dealing with a complicating factor (the reverse thrust warning), which was not covered in recurrent training, combined with probable startle effect due to the unexpected bird strike. While accomplishing the engine failure after $V_1$ procedure, these factors caused the crew, especially the Captain, to manifest only a few "high automatic" (well-ingrained) skills, such as achieving the initial pitch angle, initial maintenance of heading, and the engagement of the autopilot, without being in control of the overall situation.

The Commission notes that the Captain's and First Officer's last psychological evaluations were conducted by the Operator (the Aeromedical Expert Commission is a branch of the Operator) in accordance with the requirements of FAR CAMC-2002, annex 5, paragraph 9, "Psychology Manual for Selection, Training, and Professional Activity of Civil Controllers and Flight Crews in the Russian Federation," approved by directive No. 57 of the Russian Ministry of Transport on 31/10/2000 (henceforth, the Manual), which defines the norms for psychological evaluations and includes the document regulating their conduct.

The Manual defines the Standardized Multifactor Personality Analysis (SMPA) as one of the basic methods of personality analysis in civil aviation medicine. The Manual allows the use of both physical and computerized forms of the test. In practice, the computerized form is used. The interpretation of the results was also conducted in accordance with the provisions of the Manual. Therefore, the test results were trustworthy and within the limits of established norms.

At the same time, the MAK Investigation Commission has repeatedly noted that the psychoanalytical methods used to determine individual personality traits in civil aviation are primarily reliant on verbal methodologies. Therefore, test takers (pilots) with sufficiently advanced intellect can successfully manipulate the test results when verbal methods are used, by avoiding answers that could present them in a negative light. Consequently, the fact that a personality profile falls within the normal range is not by itself a sufficient basis on which to determine the subject's level of adaptation or maladaptation. Due to their investigative findings, commissions have repeatedly issued similar recommendations, including that the Manual be refined. Unfortunately, the majority of these recommendations have not been adopted.

In this case, the flight crew's psychological fitness for duty was formally affirmed in accordance with the Manual, since the quantitative indicators obtained from their tests results fell within the normal range. In reality, both crewmembers' profiles, obtained during their most recent tests, contain signs of untrustworthiness, although these signs are not described in the Manual. Therefore, because of the established negative attitude of pilots toward the test, the results that fell within the normal range according to the provisions of the Manual cannot be taken at face value, which should signal to the psychologist that additional qualitative analysis of the profile is needed, with a focus on the "weak" areas. During the analysis of the Captain's and First Officer's test results, no attention was paid to a whole series of signs, both qualitative and quantitative, which, if evaluated, would have led to a recommendation for additional investigation using non-verbal methodologies.

***Note:*** *In cases such as these, experienced psychologists can make well-founded assumptions about pilots' personality characteristics and behavioral peculiarities in abnormal situations by detecting repeating patterns with the help of a qualitative analysis, but the Manual does not provide for such an analysis.*

In the final phase of the flight (after the activation of the high angle of attack protection system), the Captain's actions were aimed toward minimizing the rate of descent. After ≈10 s after the EGPWS "PULL UP" warning, the Captain pulled his side stick back to the stop and held it in that position until the end of the recording. Due to the operational constraints of the high angle of attack protection system, the Captain's ability to change the angle of attack (lifting force) and descent path was limited (see section 1.18.5. of this report). During the interval between the initial activation of the EGPWS and the full nose up side stick input, the Captain retracted the landing gear.

***Note:*** *1. From the Captain's interview:*
*"…Near the ground I instinctively pulled fully back on the side-stick in order to reduce the vertical speed."*
*2. During the interview, the Captain stated that he did not hear the "PULL UP" warning. He said that he heard a "SINK RATE" warning, which did not actually occur. Judging by the Captain's actions, he heard and instinctively reacted to the warning just as he probably would to a "DON'T SINK" warning, but due to his heightened state of stress and the overwhelming acoustic environment in the cockpit, where multiple warnings were simultaneously sounding, this fact was not retained in his memory.*

The Commission notes that the situation that had developed by the final phase of the flight did not technically fall within the "forced landing" procedures[78] contained in the operating documentation, because the airspeed was dangerously low, no altitude margin existed, and the aircraft was being kept in the air by the high angle of attack protection system.[79] The crew also did not discuss carrying out a forced landing, and the Commission was consequently unable to determine whether the crewmembers realized that ground contact was inevitable. At the same time, the Commission notes that procedures which are obviously necessary in the event of a forced landing, such as a passenger announcement to "brace for impact," extending the flaps and gear, and shutting off the engines on touchdown, were neither discussed by the crew nor actually carried out. Moreover, shortly before impact the Captain raised the landing gear, even though all applicable procedures for a forced landing on land called for the gear to be down.

In his interview,[80] the Captain explained that he raised the gear because he believed that the landing would take place on soil that was wet from rain and that the aircraft could dig in or cartwheel. The First Officer stated that the crew did discuss this matter and that the motivation for raising the gear was as the Captain had described. In reality, however, no discussion of the topic was recorded on the CVR, and the Captain raised the gear on his own without issuing a command to do so and without informing the First Officer of his actions. Therefore, considering

[78] Procedures for a forced landing on land are not covered in simulator training.
[79] The procedures in the flight operations documentation assume that the aircraft has energy reserves, primarily altitude.
[80] See section 1.18.10. of this report.

the fact that the crew did not purposefully prepare for a forced landing, the Commission cannot exclude the possibility that at that point in the flight, the Captain noticed that the landing gear had not been retracted immediately after takeoff, and decided to stow the gear in order to reduce drag on the airplane and continue the flight (since the crew had received permission from the controller to return to the airport).

### 2.4. Analysis of Aircraft Flight Characteristics and the Possibility of Continued Flight

When using the engine takeoff thrust settings established by the manufacturer, in the event of an engine failure after $V_1$, the remaining thrust should be sufficient (without increasing power) to continue the takeoff as long as the aircraft is airworthy and the manufacturer's procedures are followed. Airworthiness regulations for two-engine aircraft required that the aircraft be able to climb at an established speed with a gradient not less than 2.4% on one engine with the landing gear retracted, and with a positive gradient with the landing gear extended.

Therefore, under the conditions of the accident flight, with one engine operating in the FLEX 49 regime and a total loss of power in the second engine, it is possible to accomplish an initial climb after liftoff with the landing gear extended and accelerate to $V_2$ by a height of 10.7 m, and to achieve a climb gradient of at least 2.4% with the gear retracted.

On the accident flight, the aircraft accelerated to $V_2$ while it was still on the runway. Liftoff from the runway occurred at a speed of nearly $V_2$ + 15 kt, so at the moment the abnormal situation developed, some energy reserves existed in comparison with a normative engine failure after $V_1$, as envisioned during certification, which should have made it easier for the crew to carry out the procedure.

On the other hand, after the bird strike, the total remaining thrust from the two engines was ≈7% less than the thrust from one engine in the FLEX 49 regime. As described in section 1.16.4.2. of this report, the actual thrust was not sufficient to achieve a positive climb gradient with the landing gear extended, nor was it possible to achieve the minimum required gradient of 2.4% with the gear retracted. Therefore, the situation that developed during the flight **was outside the anticipated operating conditions assumed during certification.** As such, the scenario discussed in this section is hypothetical and has an **educational** purpose in **drawing flight crews' attention to the importance of precisely following standard operating procedures for an engine failure after $V_1$.**[81]

The modeling results described in section 1.16.4.3. of this report show that if the crew had acted in accordance with the prescribed procedures for an engine failure after $V_1$, the flight could have been continued. The simplest method, requiring minimal crew workload, would have been to raise the landing gear, maintain a speed not less than $V_2$, center the beta target and trim out the pedal forces, and engage the autopilot. Had these steps been taken, the plane could have reached a height of 600 ft above the runway level by the time at which, in reality, it struck the ground.

At the same time, a safe outcome in this scenario would not be guaranteed, because the performance of the damaged engines could have changed at any moment, leaving insufficient thrust to continue the flight. An analysis of the operating capacity of the engines after the bird strike in relation to their certification requirements can be found in section 2.2.3. of this report.

[81] Translator's note: bolding appears in the original text.

Therefore, the likelihood of a successful return to the airport would have strongly depended on the atmospheric conditions and piloting quality (close maintenance of parameters, especially speed and the beta target, as well as the magnitude of control surface deflections).

### 2.5. Analysis of Bird Control Measures[82]

On the day of the accident, the basic document outlining bird control measures for civil aviation in the Russian Federation was the Civil Aviation Bird Safety Manual (CABS-89),[83] approved by order No. 209 of the USSR Ministry of Civil Aviation on 26/12/1988. The Commission notes that by the time of the accident, this manual was greatly out of date and did not contain the global best practices for ornithological flight safety.

According to paragraph 2.4. of the CABS-89, *"Bird control is directed towards the prevention of aircraft bird strikes near airports…."*

According to paragraph 2.5. of the CABS-89, bird control involves a variety of activities, including:

- Detection and elimination of conditions leading to large concentrations of birds at airports and in the surrounding areas;
- Visual and radar monitoring of gatherings and mass overflights of birds in aircraft movement corridors;
- Notification for flight crews of bird gatherings and mass overflights discovered in aircraft movement corridors;
- Scaring away birds gathered at airports, using specialized equipment.

The basic document describing bird safety policy at Ramenskoe Airport on the day of the accident was entitled "Bird Safety Instructions for Ramenskoe Airport," approved by the general director of the M. M. Gromov Flight Institute on 04/07/2018 (henceforth—the Instructions). Paragraph 1.1. of the Instructions states that it was written, in part, on the basis of the CABS-89.

According to section 2 of the Instructions, "Securing the airport grounds and surroundings," *"the airport and the associated territory used for flights should not be attractive to birds, both settled and nomadic, and within a radius of 15 km from the airport, there should not be any dump sites for food waste, cattle farms, or settling tanks."* Section 1.18.13. of this report contains a list of numerous places between 1.5 and 8.0 km from Ramenskoe Airport which were attractive to birds.

The general director of the M. M. Gromov Flight Institute repeatedly wrote to the public prosecutors' offices in the cities of Ramenskoe and Zhukovskiy concerning the legality of existing facilities located close to Ramenskoe Airport that were attracting birds. As recently as 2019, a message was sent to the public prosecutor's office in Zhukovskiy on 20/05/2019

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[82] This section is written based on the work of expert ornithologists and the document entitled *"Conclusions based on the results of the bird control research and analysis conducted in connection with the investigation into the accident involving the Ural Airlines A321 VQ-BOZ on 15/08/2019 in the vicinity of Ramenskoe, Moscow Oblast'."* Conclusions regarding bird behavior, bird control, and other ornithological aspects are based on this report.

[83] By order No. 541 of the Russian Ministry of Transport, 04/12/2020, this document was declared invalid on the territory of the Russian Federation. No other document defining ornithological flight safety processes for civil aviation in the Russian Federation exists.

requesting a review of the legality of the activities at a waste dump in the vicinity of Narkomvod street, and on 10/08/2019 to the public prosecutor's officer in Ramenskoe requesting a review of the legality of the activities of a composting plant and the decorative soil company "Grunt Eko," located in the village of Chulkovskoe (≈5 km from the runway at Ramenskoe Airport). The requests were not answered.

According to paragraph 4.1.14. of the CABS-89, *"Once every approximately 2-3 years, the aerodrome area of responsibility, or "bird-unsafe" areas, are subject to a recurrent inspection, in order to ensure that the bird safety situation has not significantly changed. If the airport is located in a densely populated area, the inspection should be conducted yearly."*

> ***Note:*** *The CABS-89 does not clearly define the meaning of the "airport area of responsibility."*[84] *Depending on context, this may be understood to refer to the area within 15 km of the airport.*
> *According to Article 47 of the Air Codex of the Russian Federation (in edition No. 135-F3 of the Federal Regulations, 1/07/2017), "the airport area of responsibility is established by decision of the federal organ granted executive authority by the Government of the Russian Federation, in order to improve aviation safety, manage airport growth, and prevent negative effects of airport equipment and aircraft movements on the health of people and the environment, in accordance with the active Codex, land legislation, and urban planning legislation, taking into account legal requirements concerning the sanitary and epidemiological well-being of the population.*
> *"The "decision" indicated at the beginning of the first paragraph, regarding the airport area of responsibility, establishes limits on the use of land and/or the properties and activities, economic or otherwise, on that land, in accordance with the active Codex (henceforth, the limits on property use and activities)." At the time of the accident, Ramenskoe Airport did not have an airport area of responsibility.*

Prior to the accident, the last ecological/ornithological inspection of the airport area of responsibility, carried out by qualified third party specialists, took place in 2010. A yearly ecological/ornithological inspection of Ramenskoe Airport and its airport area of responsibility was conducted by specialists from the M. M. Gromov Flight Institute (who were not subject matter experts) between 27 May and 10 June 2019.

Considering the airport operator's lack of current maps, current ecological/ornithological inspection data completed by subject matter experts, and proper bird observation logs, it was not possible to establish exact bird movement routes, and it can only be guessed which locations, including those described in section 1.18.13 of this report, influenced the bird situation, and to what extent.

Furthermore, gulls, such as those involved in the bird strike, have been traditionally known to prefer reservoirs located near the airport for nesting purposes. Gulls feed at dumps and agricultural fields. Among reservoirs, Lake Glushitsa should be singled out; and among dumps, any within a 15 km radius of the airport, especially the Zhukovskiy City Dump (on Narkomvod

[84] Translator's note: The original Russian phrase used is "приаэродромная территория," which literally means "territory around the aerodrome." As this does not carry the connotation of an officially defined term, "airport area of responsibility" has been chosen to more accurately reflect the intent of the phrase.

Street) and the dump in the Mikhailovskaia Sloboda neighborhood. Some of the birds' resting and overnighting locations may have been on the opposite side of the Ramenskoe airport runway from their feeding sites. Consequently, the gulls would fly out to their feeding sites and then return to their rest spots, in the process crossing the runway and endangering aircraft movements.

Considering that the accident occurred at 03:15 (during daylight hours), the gulls either overnighted at the airport (directly on the runway or nearby), or they overnighted at another location, but discovered a food source near the runway early in their daily movements and stopped to feed. It was also possible, although less probable, that the birds overnighted in some other location, but were disturbed and flew away, then discovered a suitable place to sleep in the area near the runway. In any case, the gulls arrived in the runway area while it was light out, either on the evening before the accident, or that very morning, after sunrise.

Between 01:31 and 01:36, the previous flight, using the same aircraft but with a different crew, landed, rolled out, and taxied off the runway. No further takeoffs or landings occurred at the airport until the accident flight. The landing was conducted on Runway 30, so the rollout and taxi occurred in the same areas where the crew and passengers of the accident flight saw birds, including the site of the bird strike. If the gulls had spent the night near the airport runway, then the airplane moving past them should have startled them, but they did not abandon the area. Most probably, the gulls took off, circled for several minutes, then set down not far away. The landing took place in twilight, and the crew did not report seeing birds.

According to the airport director's statements (see section 1.18.7. of this report), he conducted a runway inspection between 02:30 and 02:50 (in daylight conditions) and did not notice any birds. Per his statement, the route of the inspection passed through the area where the crew saw birds during taxi, and through the immediate vicinity of the bird strike location. Because of the lack of objective data, primarily due to numerous deviations from existing inspection procedures, the Commission did not consider it possible to confirm whether the runway inspection was in fact conducted.

At the same time, the probability that car would disturb the birds is low, especially if they were sitting off to one side of the runway, rather than on the runway itself, because for gulls, a car passing by is a completely normal occurrence.

It is also important to consider that birds may gradually move toward areas of the surface that have started to warm up after sunrise,[85] and gulls like to sit on warm concrete and asphalt if the location is open and safe. It was also possible that the gulls were located in the dense grass near the runway, because the height of the grass was up to 15 cm.

According to the Instructions, section 3, "Organization of bird control and airport staff duties," during August and September, birds appear in large flocks in open areas, including at Ramenskoe Airport. As a result, the greatest danger to aircraft is presented by large flocks of gulls made up of up to 150 individuals, which sit on the concrete surface of Runway 12/30 near the B5A taxiway (see Fig. 29 for a map of the taxiways), and occasionally at the western threshold of Runways 12/30 and 08/26, known as the "fan." The Commission notes that the bird strike occurred between taxiways B10 and B5A, and that the crew first observed birds not far from the "fan."

Most probably, the accelerating aircraft scared the birds, and they rushed to take off and gain altitude. Birds prefer to take off into the wind (just like the aircraft), because this makes it easier to gain altitude quickly. Sometimes, in order to catch predators by surprise, they will move

[85] Sunrise on the day of the accident took place at about 02:00.

across the path of the approaching danger. This was most probably why the gulls suddenly cut across the aircraft's takeoff course.

According to the bird control equipment location map, working acoustic devices were installed at the point where the carcasses of gulls killed in the collision were found (to the east of taxiway B10, on the north side of the runway), and also at the point where a flock of birds was seen on the passenger video (near taxiway B9, south of the runway). A propane cannon was also installed near taxiway B9.

*Figure 93. Map of the locations of bird control equipment at Ramenskoe Airport*

The acoustic devices were equipped with chips programmed for defense against gulls, including European herring gulls. Information about the tuning of the devices at the time of the

accident is not known, because the airport operator does not publish their operating regimen. The Commission was only able to establish that the bird control equipment was in round-the-clock operation and worked throughout the night.

With the acoustic devices and propane cannons in continuous operation, they could have scared away the birds as soon as they arrived in the equipment's operating range (before the incident), in which case, by the time of the accident, the birds would have already abandoned the defended zone. If this did not immediately happen, then it is improbable that the birds would have reacted to subsequent acoustic signals and cannon fire, because there was no fundamental difference in the signals and cannon fire during their subsequent cycles of operation.

This conclusion is supported by the ICAO Airport Service Manual (see section 1.18.11. of this report). This manual states that propane cannons and acoustic devices should be used only intermittently in order to scare away specific flocks. Using these devices in a continuous operating regime (as was done at Ramenskoe Airport) causes the birds to become accustomed to the signals, rendering them ineffective. The Commission notes that the bird control equipment operational procedures at Ramenskoe Airport did not correspond to the provisions of the ICAO Manual. The installed equipment did not exclude the presence of a large quantity of birds in dangerous proximity to the runway. It is also worth mentioning that the airport operator's bird control service was not fully staffed with specialists possessing subject matter expertise.

***Note:*** *Recommended utilization of propane cannons and acoustic devices, CABS-89 (mostly similar to the provisions of the ICAO Manual):*

*"4.7.3.4. In order to scare away feeding or resting birds, acoustic blasts should be generated 2-3 times in a row. One blast lasts for 15-30 seconds, followed by a pause of 10-20 seconds. Birds will usually take flight after the first blast, and often, although not always, fly in the direction of the source of the noise and circle it for a short time. At that point the second blast begins, after which the birds will abandon the airport area. Sometimes they leave immediately after the first blast.*

*4.7.2.5. In order to scare away overnighting birds in the evening, issue two 20-30 second blasts with a 10-15 second interval while the birds are gathering for the night. Birds often leave after this, only to return after 5-10 minutes. During this time, another series of blasts will cause the birds to abandon their overnighting location. If this type of deterrence is used daily for 3-4 days, the birds may be discouraged from using this overnighting location for a long time. The reason for scaring away overnighting birds is that they present a significant danger to aircraft transiting the airport area during evening and morning."*

*Evidently, these excerpts concern active deterrence by a human operator, because they call for a series of sequential blasts aimed at a particular flock (which is feeding, resting, or overnighting), and deterrence equipment operated automatically, as was done at Ramenskoe Airport, cannot guess when exactly the birds will be in its operating range.*

Ornithologists stress that neither bird call devices nor propane blasts are absolutely effective and should only be used in combination with other means. This same point is included in the ICAO Manual.

Among the means of deterrence that are listed as effective against gulls are the chemical Avitrol (not usable in the Russian Federation) and the placement of dead gulls on poles: *"Experience with dead gulls and crows hanged from poles has shown promising results in terms of deterring these types of birds from feeding and resting locations. In order to achieve the maximum degree of success when using dead birds for deterrence, the birds should be suspended in the "death pose." Live birds do not pay attention to dead birds on the ground, lying on their backs, or in roosting or overnighting sites; on the contrary, they find such sights interesting and will approach them."*

In sum, after conducting research, the ornithologists came to the following conclusions:

- The gulls almost certainly stopped at the location of the bird strike in the evening on the the day before the accident (before 17:07), or that morning after sunrise.
- The birds at the accident site were either sleeping or feeding, and it was unlikely that the airport director disturbed them during the runway inspection (if it was conducted).
- It was impossible to establish where exactly the birds arrived from, or their route, due to the lack of bird inspection records or maps from the time of the accident.
- It was not possible to definitely establish what equipment, operating regimes, and locations would be necessary to defend the airport, since neither the CABS-89 nor the corresponding FARs nor the equipment's operating instructions include exact directions. However, the CABS-89 repeatedly emphasizes that several questions (including choices between several means of deterrence and possible locations) should be guided by the recommendations of specialists from local biological institutions. Furthermore, a wide range of methods in use around the world are not described in the CABS-89. In particular, the majority of the actual data are included in ICAO Doc 9137, part 3 (5$^{th}$ edition).
- In total, the airport operator's bird control documentation met the requirements of the CABS-89 and the corresponding FARs; however, the "Bird Control Instructions for Ramenskoe Airport" do not contain a complete enumeration of all the facilities in the vicinity of the airport that might influence the bird conditions, nor do they contain any directions concerning the necessity of cooperating with these facilities. Furthermore, the bird condition observation log was filled out irregularly at the time of the accident (for example, there are no data for the 14$^{th}$ or 15$^{th}$ of August 2019), and it included only the most general information, such as the date, time range of observation (usually large ranges, often the entire day), area of observation (also highly general, for example, "runway"), and the genetic classification of the observed birds (usually on the family or genus level).

Based on the results of this analysis, the Commission generally concludes that the adverse bird situation that existed at Ramenskoe Airport during the examined period of the year, along with the presence of a large number of locations attractive to birds close to the airport, and deficiencies in the bird control measures, which were due, in part, to regulatory and advisory bases that are obsolete or lacking updates, created additional flight safety risks and were causal to the accident.

## 3. Conclusions

3.1. The aircraft accident involving A321-211 VQ-BOZ occurred during takeoff in daylight hours (06:15 local time) and under visual meteorological conditions as a result of a collision immediately after liftoff with a flock of gulls with masses greater than 1.13 kg (2.5 lbs), considered to fall within the "large bird" certification category, which caused mechanical damage to both engines, a decrease in total available thrust below the thrust of one engine in FLEX 49 (the regime under which takeoff was conducted), an inability to continue the flight[86] with the existing aircraft configuration (gear in the extended position), and a forced landing outside the airport. Considering the available engine thrust, the situation that developed during the flight fell outside the expected operating conditions envisioned during certification of the aircraft type. Based on the damage to the engines, maintenance of even this thrust level during continued flight would not have been guaranteed.

3.2 Taking into account the fact that the situation fell outside the expected operating conditions—namely, the lack of standard operating procedures for the actual situation, and the manufacturer's position, presented during the investigation, that the possibility of safely continuing the flight under the conditions was critically dependent on piloting skill (the actions of the crew during maneuvering, turnback, etc.) and outside factors (wind shear, turbulence)—it was not considered possible to unambiguously classify (or name as contributing factors) the risk factors identified during the investigation. As such, and because these risk factors still create flight safety risks and demand mitigating measures, these factors are presented below:[87]

- The CABS-89, the active document defining the requirements for bird control in the Russian Federation at the time of the accident, did not correspond to its ICAO counterpart, global best practices, or modern ornithological knowledge. By order No. 541 of the Russian Ministry of Transport, 04/12/2020, this document is no longer in force. No other document defining the requirements for bird control has been adopted, which creates unacceptable risks under the current adverse bird situation at numerous airports in the Russian Federation.
- There were many locations attractive to birds (reservoirs, dumps, farmland, etc.) near the airport, including dumps in locations that did not correspond to the provisions of the Ramenskoe Airport Bird Control Instructions.
- There were deficiencies in the organization of the bird control program at Ramenskoe Airport, including its ecological/ornithological inspections, bird deterrence measures, and airport surface inspection.
- There was a practice (not only at Ramenskoe Airport) of constantly informing crews about "bird activity" regardless of the level of risk, as a result of which this information lost any warning effect and became familiar "white noise."
- There were no provisions in the regulatory documents or standard operating procedures regarding the actions to be taken in situations where the crew has reason to suspect (but no ability to observe) the presence of birds in close proximity to the runway that might affect the safety of the flight.
- The actual situation that developed during the flight differed from simulator scenarios (due to the false generation of an open left engine thrust reverser message, caused by a

[86] An inability to simultaneously maintain altitude and speed even after placing the thrust levers in the takeoff position.
[87] Risk factors are listed in chronological/logical order without evaluating their relative priority.

bird striking one of the reverser door position sensors); there was increasing psycho-emotional pressure on the crewmembers; and consequently, the actions of the crew became temporarily disorganized while carrying out the engine failure after $V_1$ procedures, causing them to omit raising the landing gear.

### 4. Deficiencies Uncovered During the Investigation

These are described in the text of the report.

## 5. Safety Recommendations and Post-Accident Safety Actions[88]

### 5.3. Safety Actions Taken During the Investigation

5.1.1. An ecological-ornithological inspection was carried out on the territory of Ramenskoe Airport and all areas within a 15-kilometer radius.

5.1.2. The M. M. Gromov Flight Institute initiated a supplemental bird control program at the airport. Additional bird control equipment was acquired, including 4 Bird Guard Super PRO AMPs, 6 acoustic devices, 6 repellent devices, 10 dynamic bird scaring devices, and 10 "mirror ball" bird scaring devices. The number of bird control engineers was increased to 4. The number of contract bird control personnel was increased. Regular exercises are now carried out involving members of the airport technical staff and the aviation ornithological service.

5.1.3. Monthly monitoring (by helicopter overflight) is now carried out at food waste sites and intensive construction zones near the airport (with photographic documentation). Correspondence is taking place with the Ramenskoe and Zhukovsky district administrations, and the Ramenskoe and Zhukovsky public prosecutor's offices, concerning bird control at Ramenskoe Airport (via liquidation of dumps).

5.1.4. Information about the ornithological situation at Ramenskoe and several other airports was added to the Russian Federation Aeronautical Information Publication (AIP).

5.1.5. Rosaviatsiia carried out an analysis of the ornithological situation at airports in the Russian Federation, the results of which were distributed to interested organizations in Rosaviatsiia letter No. ISKh-17951/02, 21/05/2021 (Flight Safety Information 2021, No. 5).

5.1.6. On 15/02/2021, a Cooperation Agreement was concluded between Rosaviatsiia and the A. N. Severtsov Institute for Ecological Problems and Evolution of the Russian Academy of Sciences, in order to improve bird control, draw up joint proposals for minimizing bird strikes, and take progressive administrative steps. Under the Cooperation Agreement, a joint effort was initiated to aggregate all bird strike data and determine the species of birds involved in collisions, in order to support recommendations for managing bird behavior and limiting airports' attractiveness to birds. To these ends, in addition to the bird strike reporting form already drafted by Rosaviatsiia, Rosaviatsiia letter No. ISKh-17951/02 (Flight Safety Information 2021, No. 5) recommended that airport operators send biological material from birds involved in bird strikes to the A. N. Severtsov Institute (as recommended by paragraph 1.1.1 of ICAO document No. 9332).

5.1.7. The Operator clarified its procedure for evaluating the risk levels at its served airports in order to make optimal use of all available information. Provision was made for deeper analyses, depending on the level of ornithological risk, based on official statistics.

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[88] According to Annex 13 of the Chicago Convention, "Investigation of Aircraft Accidents and Incidents," the issuance of recommendations "does not under any circumstances constitute a determination of guilt or responsibility for an aviation accident."

5.1.8. In order to increase flight crews' knowledge, the Operator drafted Instruction LS/I 6.1-104, "Peculiarities of flight operations at specific districts, routes, and airports." These instructions are supplementary to the information contained in Part C of the FOM, and are intended to support flight crews' independent theoretical flight preparations, as well as for use during official preliminary preparation. The instructions include specifics about airports' bird situations received from official informational publications (the AIP) and various other sources.

5.1.9. In order to comply with the provisions of Article 8, Part 1, Paragraph 1 of the Air Codex of the Russian Federation, on 07/10/2020 the Russian Ministry of Transport issued order No. 415 (registered with the Russian Ministry of Justice as No. 63699, 31/05/2021), approving the Federal Aviation Regulation, "Certification procedures for airports designated for commercial use by aircraft with more than 20 passenger seats, and airports open to international flights by civilian aircraft."

5.1.10. The aircraft manufacturer (Airbus Industry [sic]) took the following measures:

1. The description of the ENG 1 (2) REVERSE UNLOCK warning in the FCOM was revised to bring it into accordance with the ECAM logic.

2. After the accident, the following changes were made to the FCTM:

- Emphasis was added to the risk of autopilot disconnection when pedal forces are not trimmed out or when the pedals are deflected while the autopilot is engaged.
- Information was added to the procedures for an engine failure after $V_1$, stating that when the rate of climb is insufficient, it is recommended to raise the landing gear and consider moving the thrust levers to TO/GA.

3. The conditions under which the ENG 1 (2) REVERSE UNLOCKED warning is inhibited were reviewed. In the next version of the F13 warning system, which was submitted for certification at the end of 2021, this warning will be inhibited during the first 15 seconds after liftoff, which corresponds to the threshold value of 400 ft above ground level recommended in the FCTM.

4. A video aid was created, entitled "Engine failure after reaching $V_1$." The material was published on the Airbus-WIN website. Its purpose is to make the corresponding information from the Airbus Department of Flight Operations and Professional Training available to instructor pilots.

### 5.4. Flight Safety Recommendations for the Russian Aviation Authorities[89]

5.2.1. Inform civil aviation personnel and flight support personnel about the circumstances of the accident.

5.2.2. Draft and implement a regulatory act defining bird control requirements for civil aviation in the Russian Federation.

5.2.3. Together with the Russian Ministry of Industry and Trade, establish an airport area of responsibility for Ramenskoe Airport, according to the provisions of Article 47 of the Air

[89] The aviation administrations of other states participating in the Agreement should consider the applicability of these recommendations in light of the local conditions in their states.

Codex of the Russian Federation. Evaluate the need to establish airport areas of responsibility at other airports.

5.2.4. Until an airport area of responsibility is established, initiate measures to liquidate dumps and other locations attractive to birds that violate the provisions of the Bird Safety Instructions for Ramenskoe Airport.

5.2.5. Evaluate the inclusion criteria of bird strike risk information in ATIS messages and other messages transmitted to flight crews.

5.2.6. Continue collecting regular data about bird strikes at airports in the Russian Federation. Based on these data, evaluate the efficacy of possible measures to reduce the risk of bird strikes at specific airports.

5.2.7. Review the expediency of introducing the concept of an "adverse bird situation" at the airport during specified periods of the year and/or times of day; establish criteria for declaration of such a situation and additional standard operating procedures for airport workers and crewmembers during these conditions (for example, additional runway inspections following any break in aircraft movements and mandatory reporting by crews of bird sightings near or on the runway).

5.2.8. Review the expediency of expanding FAR Part 128 with provisions governing crew and support personnel actions during situations in which the crew has reason to suspect (but no ability to observe) the presence of birds in close proximity to the runway that might affect the safety of the flight.

5.2.9. Conduct an analysis of the provisions of the Psychology Manual for Selection, Training, and Professional Activity of Civil Controllers and Flight Crews to determine its compliance with modern psychological knowledge, including the efficacy of current methodologies for pilot personality tests, considering forms of emotional response and behavior during abnormal situations.

5.2.10. In connection with the discovery of systematic flight crew duty time limit violations, direct special attention to this area during inspections of airlines, and draft and implement a set of systemic actions to eliminate this risk factor.

5.2.11. Use the Russian representative at ICAO to clarify the Russian translation of the ICAO Airport Services Manual (Edition 5, 2020), Part 3, "Preventing Adverse Presence of Birds and Wild Animals" (Doc 9137) (see section 1.18.11). Review of the applicability of this recommendation to the Russian versions of other ICAO documents.

**To the M. M. Gromov Flight Institute:**[90]

[90] Other airport operators should review the expediency of complying with this recommendations, considering their local circumstances.

5.2.12. With the participation of subject matter experts, evaluate the effectiveness of the measures taken to improve the bird situation at Ramenskoe Airport, as well as the adequacy of the procedures and equipment for timely observation and deterrence of concentrations of birds on or near the runway. Determine the need for additional measures based on the results of the evaluation.

5.2.13. Evaluate the risks posed by the presence of irrigation canals in the area designated for forced landings. If necessary, take measures to reduce the risks to an acceptable level.

5.2.14. Take measures to staff the bird control service with subject matter experts.

5.2.15. Review the expediency of considering risks associated with increased bird activity during morning and evening hours when creating flight schedules.

5.2.16. In cooperation with the State Corporation for the Organization of Air Transport, conduct exercises with airport service specialists and air traffic controllers on coordination and communication during runway inspections and other tasks.

**To Ural Airlines:**[91]

5.2.17. Conduct crew exercises on engine failures after $V_1$, paying special attention to methods of reducing aerodynamic drag.

5.2.18. Conduct crew exercises on forced landings on land. Review the expediency of introducing this element into the simulator training program with periodic training sessions and checks.

5.2.19. Within the framework of the Safety Management System, review the expediency of periodically introducing confounding elements into simulator training scenarios for frequent exercises with a repetitive character (rejected takeoffs and engine failures after $V_1$, system failures, etc).

5.2.20. Create a list of airports with adverse bird situations. Include specific information for flight crews about ways to reduce bird strike risks at these airports in the FOM, including obligatory notification to ATC of bird sightings on or near the airport that threaten flight safety.

5.2.21. When determining the safety issues at airports and evaluating the risks they create, use all available information for that specific airport, including its flight operation instructions and its Bird Safety Instructions (when these exist).

5.2.22. Taking into consideration the possible measures taken in response to recommendations 5.2.5-5.2.8, review the expediency of introducing standard operating procedures and corresponding flight crew training on situations in which the crew has reason to

[91] Other airlines should review the expediency of implementing these recommendations, considering their local circumstances.

suspect (but no ability to observe) the presence of birds in close proximity to the runway that might affect the safety of the flight.

**To the psychologists at the Aeromedical Expert Commission and at the airlines:**

5.2.23. When conducting psychological selection, pay special attention to pilots' personality traits related to methods of emotional reaction and behavior during abnormal situations, and if adverse signs are detected, provide specific recommendations about their fitness for retraining and/or about the need to take an individual approach to retraining.

**To EASA, the FAA, MAK AR, Rosaviatsiia, and other bodies certificating aircraft, as well as aircraft manufacturers:**

5.2.24. Taking into account the information included in section 1.1.1 of this report, review the expediency of providing for the possibility of a rejected takeoff after $V_1$ in the operating documentation, if the crew has reason to suggest that the aircraft is "just unable to fly;" for example, due to a significant reduction in total engine thrust, an inability for whatever reason to achieve the takeoff angle of attack, or a substantial reduction in the lift coefficient, due, for instance, to unremoved ground icing. For runways where the available rejected takeoff distance makes it practicable, add these procedures to the takeoff calculations.

5.2.25. Taking into account the provisions of the certification documents permitting the thrust levers to be moved from one position to another in no more than 10 seconds during bird resistance certification tests (that is, permitting very slow movement), review the expediency of adding a recommended thrust lever movement speed to the operating documents, in the event that the crew suspects mechanical damage to an engine (for example, as a result of a bird strike), or some other similar information that would increase crew knowledge about the possibility of a loss of engine airflow stability when moving the thrust levers sharply under such conditions.

**To ICAO:**

5.2.26. Review the expediency of amending Annex 6 of the Convention on International Civil Aviation in order to prevent loss of flight recorder data during an interruption in the aircraft's electrical power supply, with provision for the presence of alternative power sources for recording devices in order to ensure uninterrupted recording of parameters for a specified period of time.

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| Commission Chairman | **K. A. Kulinskiy** |
| Commission Deputy Chairman | **B. A. Goriunov** |
| Commission Members: С особым мнением *"With dissenting opinion"* | **A. A. Averkiev** |
| | **S. K. Bez'iazykov** |
| | **V. Yu. Kiselev** |
| | **I. M. Konovalov** |
| | **R. I. Chebrov** |

**Dissenting Opinion**
**by A. A. Averkiev, member of the Commission of Investigation of the incident involving A321 aircraft VQ-BOZ on 15/08/2019 in the vicinity of Ramenskoe Airport**

1. Section 1.16.6 of the draft final report contains the results of an analysis of the flight crew members' psychological testing data. Later in the draft final report, including in the "Analysis" section, the opinion of a single expert, introduced in this section, is used to conclude that "from the very beginning of the event, the actions of the crew, especially the Captain, were characterized by disorganization, inconsistency, and chaos, indicating partial psychological incapacitation." Similar conclusions are made in relation to the First Officer.

The first paragraph of section 1.16.6 of the draft final report states that, "the analysis was carried out by a psychologist with 25 years of experience working in the field of psychiatric diagnostics (mainly clinical) at an expert level; a professorship; supervisory experience; and experience with personality evaluations in a legal context."

Evidence of the expert's qualifications and organization of origin, and the methods used in his analysis, are not presented in the final report. The report also lacks evidence confirming that previous flight fitness analyses by this expert were confirmed by other recognized specialists in this field, or that they conformed to best practices. The available evidence suggests that this expert does not possess real piloting or crew resource management skills in any aircraft, including the A321.

Furthermore, the draft final report uses the results of this analysis conducted by a single expert in order to reach unconditional conclusions regarding the reasons for the flight crew's actions.

Considering that the analysis of psychological aspects ultimately underlies the Accident Investigation Commission's conclusions regarding the flight crew's actions, and the corresponding safety recommendations, the MAK should have created a human factors working group, as recommended in ICAO circular No. 240, "Human Factors Handbook," No. 7, paragraph 2.10, "Studying the role of human factors in aviation accidents and incidents." This would have allowed an objective and multifaceted investigation of human factors issues with input from flight fitness and aeromedical specialists.

2. All conclusions described in section 1.16.6 of the draft final report are based on an expert's interpretation of the flight crew's pre-accident testing results.

The flight crew members did not receive injuries during the accident that would have precluded the possibility of holding a conversation with them or having specialists repeat the pilots' psychological examinations. Despite this, the expert did not speak to the crewmembers, which raises doubts as to the accuracy and persuasiveness of the expert's conclusions.

3. The expert conclusions described in section 1.16.6 of the draft final report do not indicate that the pilots' personality "peculiarities" could have formed a basis for their dismissal from flying duties or that they would have required any other remedial activities (for example, in terms of crew composition) in order to ensure flight safety.

In the "Analysis" section of the draft final report, the results of the psychological analysis are used to conclude that there are deficiencies with the Psychology Manual for Selection, Training, and Professional Activity of Civil Controllers and Flight Crews in the Russian Federation.

However, the report lacks any reference to, for example, ICAO recommendations or requirements, or the practices of other states, concerning regulation of techniques for psychological selection and training of flight crews. The crew's actions are examined only from the point of view of the expert's opinion, without any attempt to confirm or refute these conclusions by considering, for instance, an analysis of human capabilities or other human factors aspects.

Furthermore, subsection 2.4 of the "Analysis" section notes that "the situation that developed during the flight was outside the anticipated operating conditions," and paragraph of 2 of the "Conclusions" section states that the situation "was critically dependent on piloting skill (the actions of the crew during maneuvering, turnback, etc.) and outside factors (wind shear, turbulence)." Therefore, it can be justifiably concluded that under the conditions, controlling the aircraft required the crew to demonstrate "exceptional skill," which is not assumed under the transport category airworthiness regulations contained in FAR part 25.

Consequently, considering the actual conditions of the flight, the inclusion in the draft report of an analysis of the flight crew's "psychological fitness" appears to be based on a controversial theory, use of which carries additional risk. Considering this, and also the fact that the Aviation Accident Investigation Commission's conclusions are based on the opinion of a single expert, the recommendation to rework the Psychology Manual for Selection, Training, and Professional Activity of Civil Controllers and Flight Crews in the Russian Federation, included in paragraph 5.2.10, requires additional justification.

4. Section 1.18.8 of the draft final report states that MAK Certificate No. 088 A-M, issued to the M. M. Gromov Flight Institute, was invalidated by the adoption of Resolution No. 1283 of the Government of the Russian Federation on 28/11/2015.

The MAK Airport and Equipment Certification Commission issued MAK Certificate No. 088 A-M to Ramenskoe Airport with a term of validity until 12/11/2020, confirming that the airport was in compliance with the requirements of FAR part 139.

Under the provisions of Resolution No. 1283 of the Government of the Russian Federation, 28/11/2015, certification functions were transferred from the Interstate Aviation Committee to Rosaviatsiia. This resolution did not contain any requirement to cancel or prematurely conclude the term of validity of MAK certificates. Hence, at the moment of the accident, Ramenskoe Airport had the valid MAK certificate No. 088 A-M from 12/11/2015. Moreover, the MAK did not inform the M. M. Gromov Flight Institute that its previously issued certificate was invalid.

As such, section 1.18.8 of the draft final report contains unreliable information.

It may be suggested that the above conclusion by the MAK Commission regarding the invalidity of Ramenskoe Airport's MAK certificate at the time of the accident indicates the MAK's desire to avoid responsibility for a possibly deficient certification carried out by the same. This is obvious evidence of the intolerability of the MAK's combined role as a certificatory body and an air accident investigator.

5. Section 5 of the draft final report contains recommendations that are incomplete and insufficiently justified:

5.1. Recommendation 5.2.3 requires clarification, because it addresses "the Russian Aviation Authorities," without specifying which department is supposed to resolve the question of establishing an area of responsibility for Ramenskoe Airport.

Ramenskoe Airport hosts experimental aviation in addition to civil aviation. According to the Airport Area of Responsibility Establishment Rules, approved by Resolution No. 1460 of the Government of the Russian Federation on 02/12/2017, the establishment of an area of responsibility for experimental aviation airports is carried out by the Ministry of Industry and Trade. Representatives of the Russian Ministry of Industry and Trade were not included in the MAK's discussion of this issue or its analysis of the status of the area of responsibility establishment process at Ramenskoe Airport, even though the draft final report indicates that this matter affected the cause of the accident.

The second sentence of the recommendation, "Evaluate the need to establish aerodrome areas of responsibility at other airports," is not justified by the text of the report, the results, or Russian federal agencies' actual work plans. This sentence is essentially declaratory.

5.2. Recommendation 5.2.4 ("Until an aerodrome area of responsibility is established, initiate measures to liquidate dumps…) is declaratory and does not correspond to the provisions of Russian Federation aviation legislation. The proposed mechanism for carrying out the recommendation is baseless and is not supported by the findings of the investigation.

The declaratory character of the recommendation stems from the lack of a proposal for the mechanism and measures that the MAK believes should be carried out. At this time, locations that may attract large concentrations of birds are under continuous monitoring. Measures to eliminate conditions that increase the bird strike risk are taken in accordance with active legislation. From the report, it is unclear what additional regulatory changes in this area are necessary.

The recommendation suggests initiating measures related to locations that do not comply with the airport operator's local rules: the Bird Safety Instructions. However, under current legislation, such questions are regulated as follows: *"Under an established airport area of responsibility, placement of a site in sub-zone six that attract large concentrations of birds is prohibited."* Prior to the establishment of an airport area of responsibility, placing such a site without the agreement of the aviation authorities (for experimental aviation airports, the airport operator) is forbidden under the site placement agreement provided for by Federal Law No. 135-F3, 1 June 2017, article 4, part 3, "Concerning Changes to Individual Legislative Acts of the Russian Federation Related to the Modernization of the Process for Establishment and Use of Airport Areas of Responsibility and Sanitary Protection Zones."

5.3. Recommendation 5.2.6, "Continue collecting regular data about bird strikes," is declaratory and does not propose any additional flight safety measures.

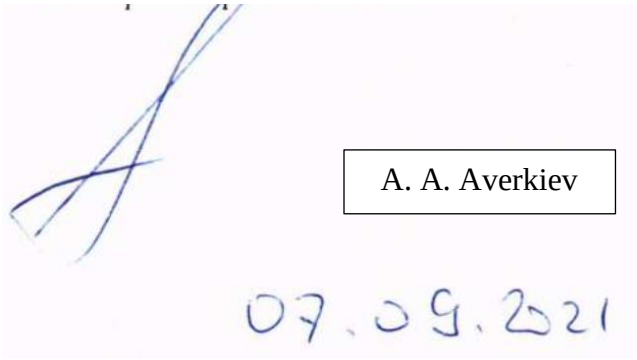
Basically, recommendations 5.2.4, 5.2.6, and 5.2.7 ("Review the expediency of introducing the concept of an "adverse bird situation…") repeat recommendation 5.2.2, concerning the need to rework ornithological flight safety regulations in connection with the cancellation of the CABS-89.

On the basis of what has been stated, I consider it necessary to:

1) Exclude section 1.16.6 and the associated text in section 2 (“Analysis”) from the draft final report. Recommendation 5.2.10, concerning refinement of the Manual for Psychological Selection, cannot be accepted because it requires additional justification.

2) Revise section 1.18.8 to exclude the unsupported conclusion that MAK certificate No. 088 A-M, 12/11/2015, was invalid at the time of the accident.

3) Exclude recommendations 5.2.3 (second sentence), 5.2.4, 5.2.6, and 5.2.7 from the report. The first sentence of recommendation 5.2.3 needs to take into account the actual status of the airport area of responsibility establishment process being carried out under the authority of the Russian Ministry of Industry and Trade.



**Commission of Investigation of the Accident Involving A321 Aircraft VQ-BOZ Response to the Dissenting Opinion of Rosaviatsiia Commission Member A. A. Averkiev**

Having reviewed (Investigation Commission meeting minutes No. 23, 06/09/2021, and the addition thereto, 08/09/2021) the Dissenting Opinion submitted by A. A. Averkiev (attached), the Commission notes the following.

The Dissenting Opinion consists of five constative sections and three suggested changes to the draft final report. The first three sections of the Dissenting Opnion and the first suggested change are related to questions surrounding the evaluation of the crew's psycho-emotional state during the accident flight; the fourth section and second suggested change are related to questions about the certification of Ramenskoe Airport; and the fifth section and its corresponding suggested change are related to the inclusion of several safety recommendations concerning the establishment of an area of responsibility for Ramenskoe Airport, the presence of sites attractive to birds, and ornithological flight safety.

**Concerning the Question about the Evaluation of the Flight Crew's Psycho-emotional State**

The Investigation Commission notes that A. A. Averkiev is not a specialist in psychology. While discussing the Dissenting Opinion, A. A. Averkiev explained that various specialists assisted him in preparing the opinion. The qualifications and fields of the experts who participated in preparing the Dissenting Opinion were not provided to the Commission. Upon the Investigation Commission's request to provide the expert analysis results or subject matter expert opinions on which this section of the Dissenting Opinion was based, A. A. Averkiev refused, explaining that, *"The Dissenting Opinion does not contain reference to the opinions or conclusions of any other specialists or experts."* Notably, A. A. Averkiev had been granted the rights and responsibilities of an Investigation Commission member, including the right to initiate and conduct research and to gather expert opinions. Considering this fact, the Investigation Commission did not find it possible to fully evaluate the persuasiveness of this section of the Dissenting Opinion. The Commission also notes that the Dissenting Opinion does not contain even one concrete observation or point of disagreement with the conclusions of the expert psychologist who worked with the Commission. All the presented observations are unrelated to the essence of the expert analysis and its conclusions.

At the same time, the Dissenting Opinion contains principal assertions that do not correspond to reality. For instance, the final paragraph of the first page of the Dissenting Opinion asserts that *"the analysis of psychological aspects ultimately underlies the Accident Investigation Commission's conclusions regarding the flight crew's actions, and the corresponding safety recommendations…."*

The Investigation Commission notes that the conclusions about the flight crew's actions are based on the flight recorder data and the flight crew interviews, and not on "psychological aspects." The fact that the flight crew's actions during the accident flight did not correspond to standard operating procedures for an engine failure after $V_1$ is objectively established by the flight recorders, and the flight crew themselves do not deny this.

Furthermore, the Investigation Commission's tasks include not only the identification of deviations in various flight crew actions, but also the analysis of possible reasons for those deviations, in order to draft safety recommendations. In this case, the Investigation Commission

analyzed all possible (known to the Commission) factors that could have affected the actions of the flight crew while carrying out the standard operating procedures for an engine failure after $V_1$. In particular, the Commission excluded the possibility that the airline's training for this procedure was incomplete, or that the crew were insufficiently trained on this matter. A. A. Averkiev has confirmed that he agrees with these conclusions by the Investigation Commission.

Considering the circumstances of the accident flight, the actual actions of the flight crew, and the explanations that they provided, the Investigation Commission established that once the abnormal situation began, the crewmembers' psycho-emotional state was suboptimal. This was the most probable reason why they failed to carry out some standard procedures, despite their successful completion of all prescribed training, including simulator and recurrent training.

Naturally, while evaluating the psycho-emotional state of the crew, the Investigation Commission studied the results of their psychological tests, since, according to the Psychology Manual for Selection, Training, and Professional Activity of Civil Controllers and Flight Crews in the Russian Federation, approved by directive No. 57 of the Russian Ministry of Transport on 31/10/2000 (henceforth, the Manual), *"the primary purpose of psychological screening lies in the achievement and maintenance of personnel capabilities that conform to the requirements demanded by their professional activities…."* An expert psychologist was recruited to work with the Commission to conduct a multifaceted analysis of this issue.

The Commission notes that the psychologist was not tasked with analyzing the results of the pilots' psychological evaluations or the interpretations thereof by Aeromedical Expert Commission staff (aviation psychologists) according to the provisions of the Manual. The psychologist was also not tasked with evaluating the actions of the flight crew during the accident flight.

The psychologist's task was to evaluate the pilots' personality traits and any possible behavioral peculiarities, drawn from such an evaluation, that would affect the pilots in abnormal situations (that is, their possible psychological reactions to an abnormal situation, and not their specific actions while flying the plane). It should be noted that this task falls well outside the scope of "standard" evaluations carried out by "line" aviation psychologists based on the methodologies in the Manual. In contrast, the personality traits and behavioral peculiarities in abnormal situations are general characteristics of a particular personality type. Therefore, the evaluation of these traits and peculiarities falls outside the scope of aviation psychology and requires broader knowledge as well as significant experience with qualitative interpretation of psychological profiles, rather than the application of quantitative, automatized methodologies. As such, conduct of such an analysis does not require piloting skills or specialization in aviation psychology. Considering the tasks described above, the Investigation Commission's choice of a psychologist with over 25 years' experience working in the field of diagnostics (primarily clinical), as well as experience with personality evaluations in a legal context, is logical and justified.

While conducting the analysis, the expert psychologist determined, among other things, that the profiles of both crewmembers, generated during their last examination, show signs of unreliability; however, these signs are not described in the Manual, even though they are contained in specialist publications (for example, L. N. Sobchik, Standardized Multifactor Personality Analysis). These conclusions were discussed with the airline's Aeromedical Expert Commission psychologist.

This means that AMEC psychologists cannot reliably interpret test results conducted under the provisions of the Manual using the usual "automatized" methods. Based on the results

of previous investigations, starting in 2006 (Crash of an A310 aircraft at Irkutsk Airport, Russian Federation; and Crash of a Tu-154 aircraft in the vicinity of Donetsk, Ukraine), commissions have repeatedly recommended that the Manual be revised. These recommendations were not adopted and the Manual has not changed since the moment of its publication. In fact, the prolonged dismissal and lack of multifaceted review and discussion of investigation commission recommendations creates the same additional flight safety risks that the author of the Dissenting Opinion rejects in the final paragraph on page 2.

Furthermore, experienced psychologists in possession of an individual's psychological testing data for a given time period can, in this case, by expertly identifying repeating patters and conducting qualitative analysis, reach justified assumptions about the individual's personality traits and behavioral peculiarities in abnormal situations. Such work has been frequently carried out by various psychologists working with investigation commissions after serious aviation accidents in past years. The results thereof have been included in final reports published on the MAK's official website.

Considering the above, and also the fact that A. A. Averkiev, while insisting on the complete exclusion of the evaluation of the flight crew's psycho-emotional state from the final report, has not suggested any other explanation for the flight crew actions captured by the flight recorders (during discussion of the Dissenting Opinion, A. A. Averkiev confirmed that he had no other explanation), the Commission decided not to make any changes to this section of the draft final report, and to append the Dissenting Opinion and the response thereto to the final report.

Separately, the Commission would like to stop at the next paragraph of the Dissenting Opinion: *"Furthermore, subsection 2.4 of the "Analysis" section notes that "the situation that developed during the flight was outside the anticipated operating conditions," and paragraph of 2 of the "Conclusions" section states that the situation "was critically dependent on piloting skill (the actions of the crew during maneuvering, turnback, etc.) and outside factors (wind shear, turbulence)." Therefore, it can be justifiably concluded that under the conditions, controlling the aircraft required the crew to demonstrate "exceptional skill," which is not assumed under the transport category airworthiness regulations contained in FAR part 25."*

While discussing the Dissenting Opinion, the Investigation Commission repeatedly asked A. A. Averkiev to clarify whether this quote means that, in his opinion, the Airbus A321 does not meet airworthiness requirements in this area. In reply, A. A. Averkiev explained that he *"considers incorrect this explanation of the indicated paragraphs of the Dissenting Opinion, and suggested that the Commission put together an argument based on the overall meaning of his points."*

The Commission notes that nowhere else in the Dissenting Opinion is there any information or analysis of whether the aircraft meets (or does not meet) airworthiness requirements (aviation regulations). Therefore, the Commission does not fully understand the meaning of the assertions in the Dissenting Opinion.

At the same time, the Investigation Commission notes the absurdity (lack of technical meaning) of the indicated paragraph. Certification of aircraft is conducted with the assumption that it will be operated under expected conditions, which are defined in FAR part 25, as *"the conditions that are known from experience or the appearance of which could reasonably be foreseen during the lifetime of the aircraft, taking into account is use case. These conditions include flight parameters and environmental factors affecting the airplane, and operational factors affecting flight safety."* When the aircraft departs the boundaries of expected operating conditions, as occurred during this case with the remaining available thrust during the engine

failure after $V_1$, the application of airworthiness norms has no technical meaning and is therefore absurd.

**Concerning the Question of the Certification of Ramenskoe Airport**

The Commission notes that its position is clearly and unambiguously presented in section 1.18.8 of the final report.

On 12 November 2015, the MAK Airport and Equipment Certification Commission issued Certificate No. 088 A-M, in accordance with the process established in Volume 1 of the Airport Certification Rules, FAR Part 139 "Certification of Airports" (henceforth, FAR 139 vol. 1). This certificate attested that Ramenskoe Airport met the certification requirements in FAR 139.

FAR part 139 established an unambiguous connection between the certificate holder's responsibility to carry out obligations, including to provide the certificating body with the necessary information, and the rights of the certificating body to conduct inspections and revoke the certificate (volume 1, paragraph 2.3).

Since 10/12/2015, when Directive No. 1283 of the Government of the Russian Federation, 28 November 2015, went into effect, the power to certificate airports in the Russian Federation has belonged only to the Federal Air Transport Agency, Rosaviatsiia. While discussing the Dissenting Opinion, A. A. Averkiev indicated that in his opinion, the contents of section 1.18.8 of the final report do not correspond to the provisions of this directive, although he did not present any specific points. The Commission notes that the directive only transfers the power to certificate airports in the Russian Federation from the MAK to Rosaviatsiia, and does not contain any provisions related to previously issued MAK certificates.

As such, starting from 10/12/2015, the MAK was not able to compel the certificate holder for Ramenskoe Airport to carry out its responsibilities as described in FAR part 139, volume 1, paragraph 2.2, or to exercise the rights of the certificating body, described in FAR part 139, volume 1, paragraph 2.3.

Moreover, by order No. 11 of the Russian Federation Ministry of Transport on 25 January 2016, order No. 48 of the Russian Federation Ministry of Transport, 5 July 1994, was cancelled, as a result of which FAR part 139 itself ceased to be valid on the territory of the Russian Federation.

Therefore, the following did not exist on the day of the accident:

- The authority of the MAK to act as the certificating body for airports in the Russian Federation; to require the fulfilment of certain previously indicated obligations from the certificate holder; or to monitor the fulfilment thereof.
- Any obligations before the MAK, described in the certification regulations and in accordance with which the certificate was issued, on the part of the certificate holder for Ramenskoe Airport.
- The very certification regulations and requirements, in accordance with which Certificate No. 088 A-M was issued; which means that, effectively, Certificate No. 088 A-M was invalid.

It also must be noted that an analogous conclusion related to MAK certificate No. 036 A-M, 27/02/2015, for Yakutsk Airport, is included in section 1.18.2 of the Final Report on the

Results of the Aircraft Accident Investigation Involving RRJ-95B Aircraft RA-89011 on 10/10/2018. This final report, which was signed without comment by all Commission members, including the Rosaviatsiia representative, has been published on the MAK's official website.

In the last paragraph of section 4, A. A. Averkiev makes a supposition that, "*the above conclusion by the MAK Commission regarding the invalidity of Ramenskoe Airport's MAK certificate at the time of the accident indicates the MAK's desire to avoid responsibility for a possibly deficient certification carried out by the same.*" The Investigation Commission notes that during the course of its work, no deficiencies in the certification of Ramenskoe Airport in 2015 were presented. A. A. Averkiev, being a member of the Investigation Commission with the same rights and responsibilities as other Commission members, did not express any comment on the question of certification. Furthermore, A. A. Averkiev is executing the responsibilities of the head of Rosaviatsiia's airport activities department, which directly handles questions related to airport certification; that is to say, he bears responsibility for the fact that Ramenskoe Airport has lacked a certificate for a considerable length of time. The Commission believes that A. A. Averkiev's suggestion to completely eliminate section 1.18.8 because it contains what he calls "unreliable information" is the proposal of a subjectively interested official who is ignoring obvious facts in order to uphold the departmental interests and *esprit du corps* of Rosaviatsiia.

> ***Note:*** *Based on the results of inspections of the civil aviation system in the Russian Federation, carried out under ICAO's universal flight safety monitoring program, auditors have noted that existing structures do not guarantee the independence of serious aviation incident investigations carried out by Rosaviatsiia. Furthermore, an impartial and independent approach is also not guaranteed when Rosaviatsiia representatives participate in aviation accident investigations.*

Considering the above, the Investigation Commission decided not to make any changes to this section of the draft final report, and to append the Dissenting Opinion and the response thereto to the final report.

**Concerning the Questions about the Safety Recommendations Section**

Having reviewed this section of the Dissenting Opinion, the Investigation Commission decided to partially adopt A. A. Averkiev's suggestions. Therefore, changes have been made to the text of the recommendation related to establishment of an area of responsibility for Ramenskoe Airport. This recommendation is addressed, among others, to the Russian Ministry of Industry and Trade, because Ramenskoe Airport is an experimental aviation airport.

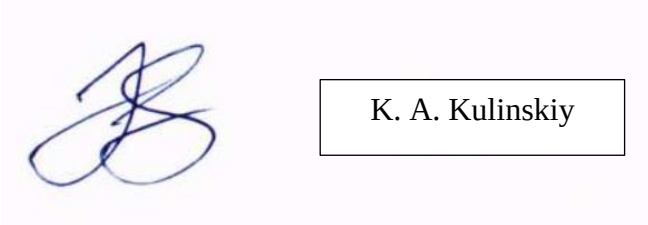
However, the Investigation Commission notes that A. A. Averkiev's remaining suggestions, concerning the elimination of recommendations directly related to his official responsibilities at Rosaviatsiia, are most probably dictated in defense of departmental interests.

In particular, in support of excluding recommendation 5.2.4, *"Until an aerodrome area of responsibility is established, initiate measures to liquidate dumps and other locations attractive to birds that violate the provisions of the Bird Safety Instructions for Ramenskoe Airport,"* A. A. Averkiev states that in his opinion the recommendation *"is declaratory and does not correspond to the provisions of Russian Federation aviation legislation. The proposed mechanism for carrying out the recommendation is baseless and is not supported by the findings of the investigation."*

The Commission notes that this recommendation, like all the others, is clear, specific, and directed at the elimination of a clearly defined problem revealed during the investigation. Furthermore, it is not the responsibility of the Investigation Commission to work out the mechanisms by which a recommendation may be realized, including determining who will implement the recommendation and over what timeframe. According to paragraph 2.10.8 of the Rules for Investigating Aviation Accidents and Incidents in the Russian Federation, approved by Directive No. 609 of the Government of the Russian Federation on 18 June 1998 (henceforth, the RIAAI), responsibility for organizing corrective actions in response to a recommendation belongs to Rosaviatsiia and the Russian Ministry of Industry and Trade. Furthermore, the Investigation Commission notes that the interdepartmental instructions contained in paragraph 2.10.11 of the RIAAI, which defines *"the process for revising, agreeing upon, and approving corrective actions, their costs, their financing, and monitoring of their implementation, as well as reporting thereof to the executive organizations, co-executors, and the body that initiated the investigation,"* have still not been developed by Rosaviatsiia, which prevents effective review of recommendations issued by aviation accident investigation commissions and negatively affects civil aviation safety in the Russian Federation. Indicators of the aviation safety level in the Russian Federation are substantially lower than the world average; furthermore, the reoccurrence of aviation accidents due to the same causes that were unambiguously determined by investigation commissions, and which were addressed by specific recommendations, remains unacceptably high.

Considering the above, the Investigation Commission decided not to change the remaining recommendations, and to append the Dissenting Opinion and the response thereto to the final report.

Chairman of the Aviation
Accident Investigation Commission



K. A. Kulinskiy

### BEA's Significant comments: Rejecting take-off after V1[92]

The draft final report refers to the possibility of rejecting a take-off after V1 if the crew have reason to believe that the aircraft is unable to fly.

Paragraph 1.18.15 (page 144)

The draft final report states: *"The analysis of the potential sequence as for these cases is the evidence that rejecting takeoff after V1 at the first sign of the inability to proceed the flight (to be airborne) would significantly reduce the speeds at RWY excursion, and most probably, the event severity."*[93]

This implies considering a possible rejection of a take-off after V1 which Airbus and the BEA do not support. Should the IAC [MAK] maintain this assumption, the BEA requests that the following note is added:

The aircraft manufacturer, Airbus, and the BEA do not support the possibility of rejecting a take-off after V1. This proposal is not relevant to the investigated accident: the birdstrike occurred once airborne, at an airspeed ~15 knots above V1, and when the right engine was still delivering power; the aircraft was able to fly and there was no reason for the crew to suspect a subsequent degradation in performance, which was primarily caused by the landing gear remaining extended.

For other cases not relevant to the investigated accident, Airbus and the BEA consider that referring to the possibility of rejecting a take-off after V1, whatever the reason, is counter-productive in terms of global safety and should be removed.

1. Take-Off speeds (V1, VR, V2, …) are defined by the certification requirements. These requirements define that V1 is the maximum speed at which a Rejected Take-Off (RTO) can be initiated. Therefore, rejecting a take-off after V1 would imply non-compliance with the current certification standards.
2. The take-off performance calculation ensures that the aircraft can be flown in the event of an engine failure after V1. The certification of the aircraft is based upon this hypothesis taking into account the aircraft performance and appropriate pilot actions. Significant training efforts have been made to ensure crews carry out the correct actions in the event of an engine failure after V1.
3. The aviation industry has made a number of safety initiatives to globally reduce the number of rejected take-off (RTO) accidents, one of them being the FAA Take-off Safety Training Aid. Considering a possible rejection of a take-off after V1 is to go in the opposite direction to these initiatives.
4. Above 100 kts and below V1, the crew are trained to develop a "GO" state of mind. V1 is considered to mark the end of the STOP or GO decision-making process. Therefore, at the latest, this decision must be made at V1, so that the Captain can initiate the STOP actions as close to V1 as possible. Considering a possible rejection of a take-off after V1 would endanger the required "GO" mindset and may result in improper RTO decisions,

[92] Translator's note: This section was appended in English to the original report and has not been altered.
[93] Translator's note: This is the BEA's own translation of the excerpt in question. A different (and better) translation is used in the translated report itself.

potentially resulting in longitudinal runway excursions, and/or an exceedance of the maximum brake energy with subsequent brake fire.

5. The aviation industry has maintained for many years that rejecting a take-off above V1 must not be considered and must not be executed. There are many sound reasons for this safe practice, not least the extremely limited time to analyse the faults and performance during a critical phase of flight. Moreover, the lack of time to precisely assimilate all useful information by the crew may lead to unsafe actions and less safe conditions.

Recommendation 5.2.24 (page 215)

The draft report includes the following recommendation: *"Taking into consideration the information, stated in section 1.18.15 of the Report, to prevent the runway excursion of the aircraft at high speed consider appropriateness of complementing the operational documentation with the provisions on the possibility of rejecting a takeoff after V1, if the crew have reason to believe that the aircraft is just unable to fly, for instance, due to a significant decrease in the total thrust of the engines, the impossibility to establish takeoff pitch (AOA) for any reason or a significant decrease in the lift coefficient, for example, due to unremoved ground icing. For runways, where practicable based on ASDA, complement the takeoff computation procedure."*[94]

Airbus and the BEA do not support a possible rejection of a take-off after V1, whatever the reason. Should the IAC maintain this assumption, the BEA request that the following note is added:

Taking into account the note in section 1.18.15, the aircraft manufacturer, Airbus, and the BEA question the safety benefit of this recommendation. This Safety Recommendation implies negative training that could result in improper RTO decisions. It would e counterproductive in terms of global safety and should be removed.



[94] Translator's note: This is the BEA's own translation of the excerpt in question. A different (and better) translation is used in the translated report itself.